The Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE™) Model and Fatigue Avoidance Scheduling Tool (FAST™)

Fatigue and Alertness Management using the *SAFTE*™ model and *FAST*™

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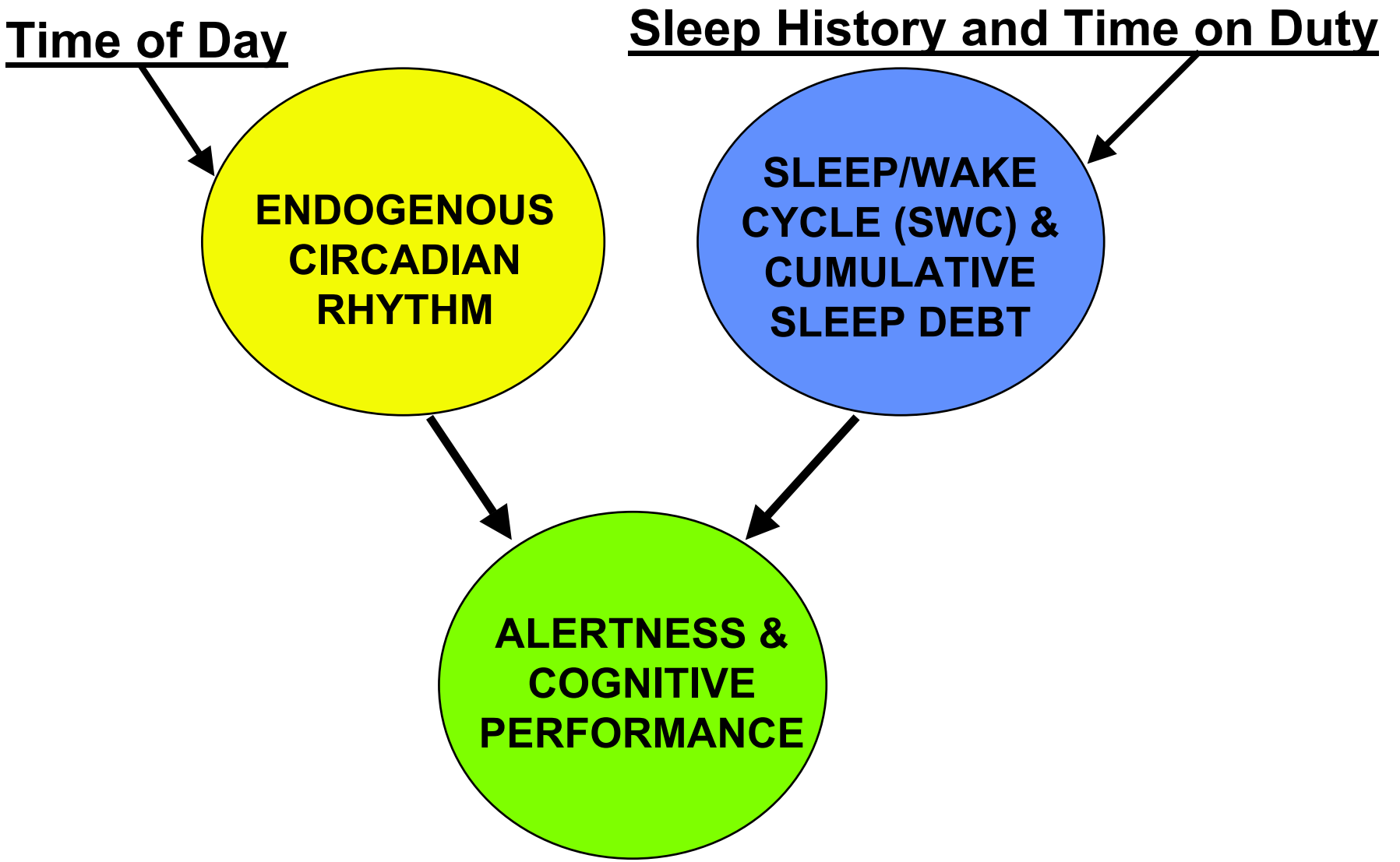
Purpose

- Review the basic concepts of fatigue and time-of-day effects on cognitive performance.
- Review the DoD *Sleep, Activity, Fatigue, and Task Effectiveness* (SAFTE) Model.
- Review and Demonstrate the Fatigue Avoidance Scheduling Tool (FAST™).

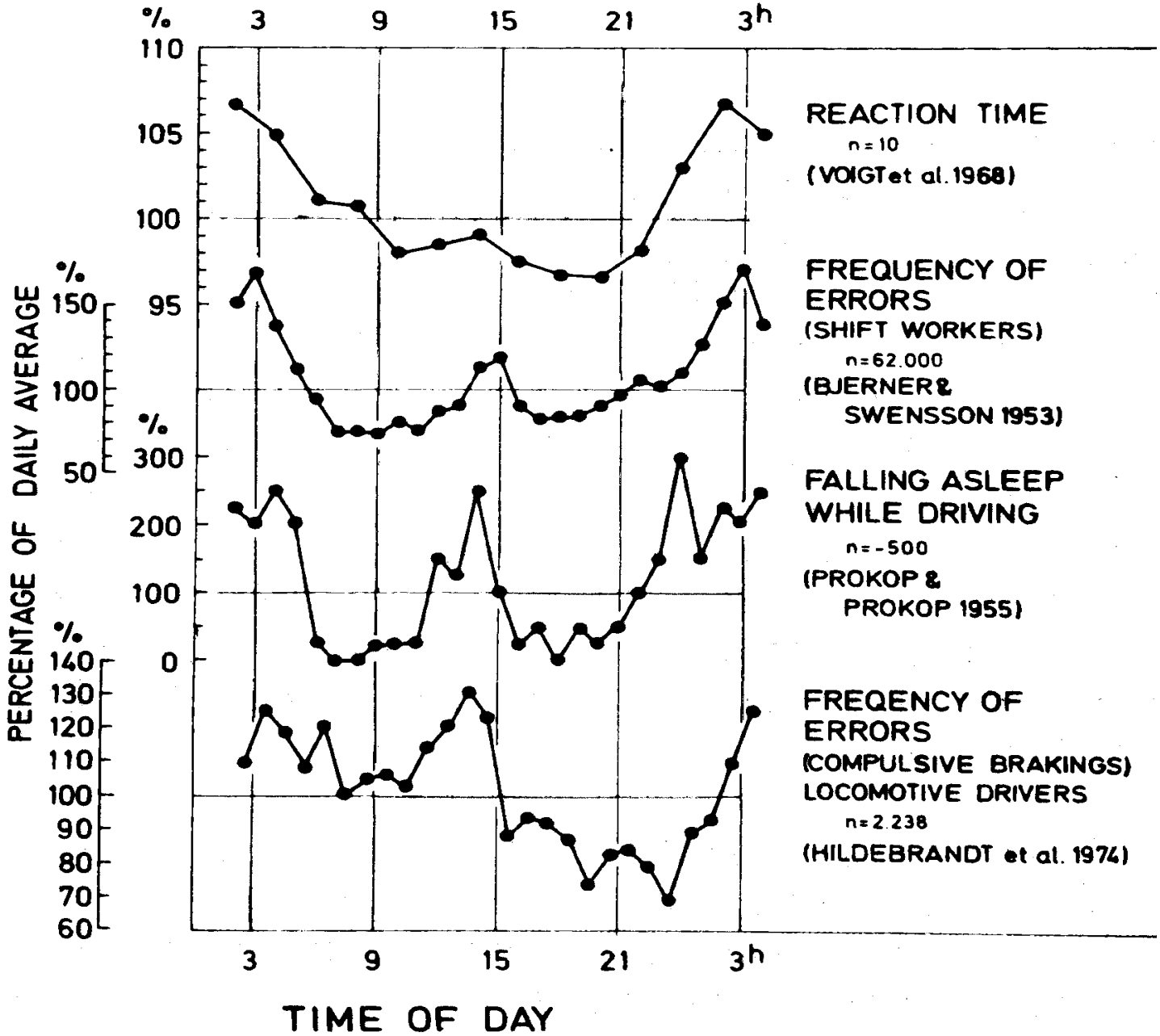
Fatigue Effects on Performance

- ✓ Impaired logical reasoning and decision-making
- ✓ Impaired vigilance and attention
- ✓ Slowed mental operations (e.g. arithmetic)
- ✓ Loss of situational awareness
- ✓ Slowed reaction time
- ✓ Short cuts and lapses in “optional” or self-paced behaviors

ALERTNESS & COGNITIVE PERFORMANCE



Circadian Rhythms of Vigilance Related Degradations



CIRCADIAN RHYTHM IN SLEEP RELATED TRAFFIC ACCIDENTS (Israel, 1984-1989)

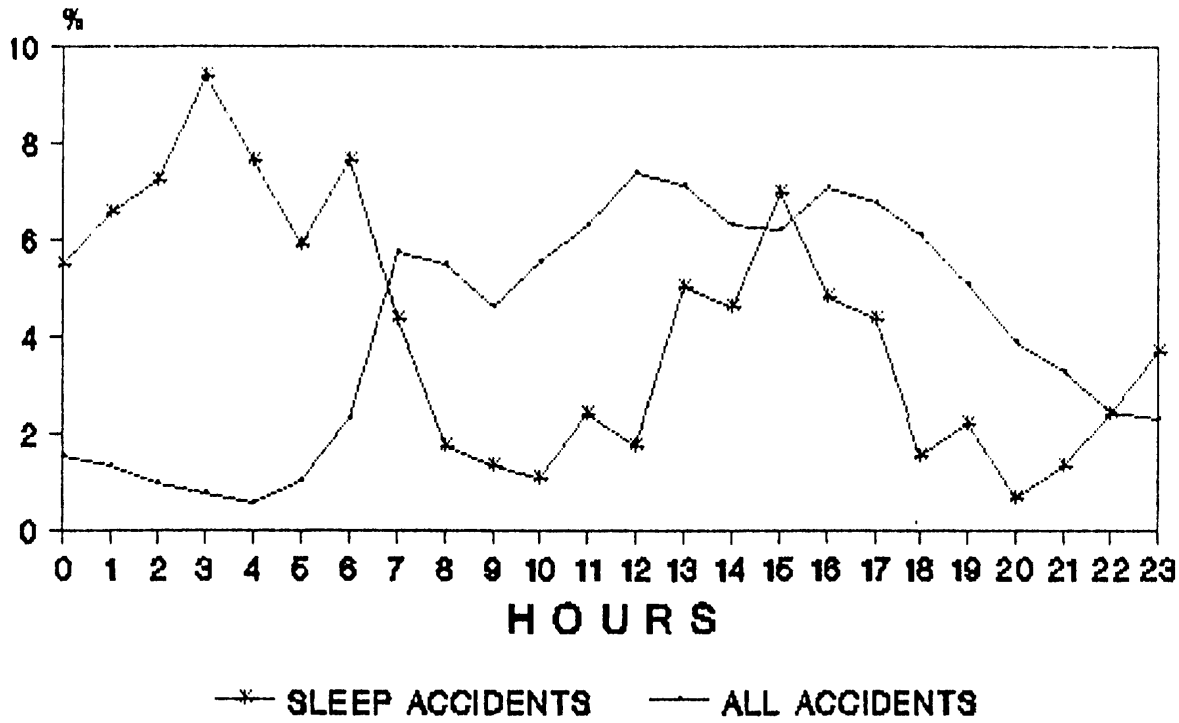
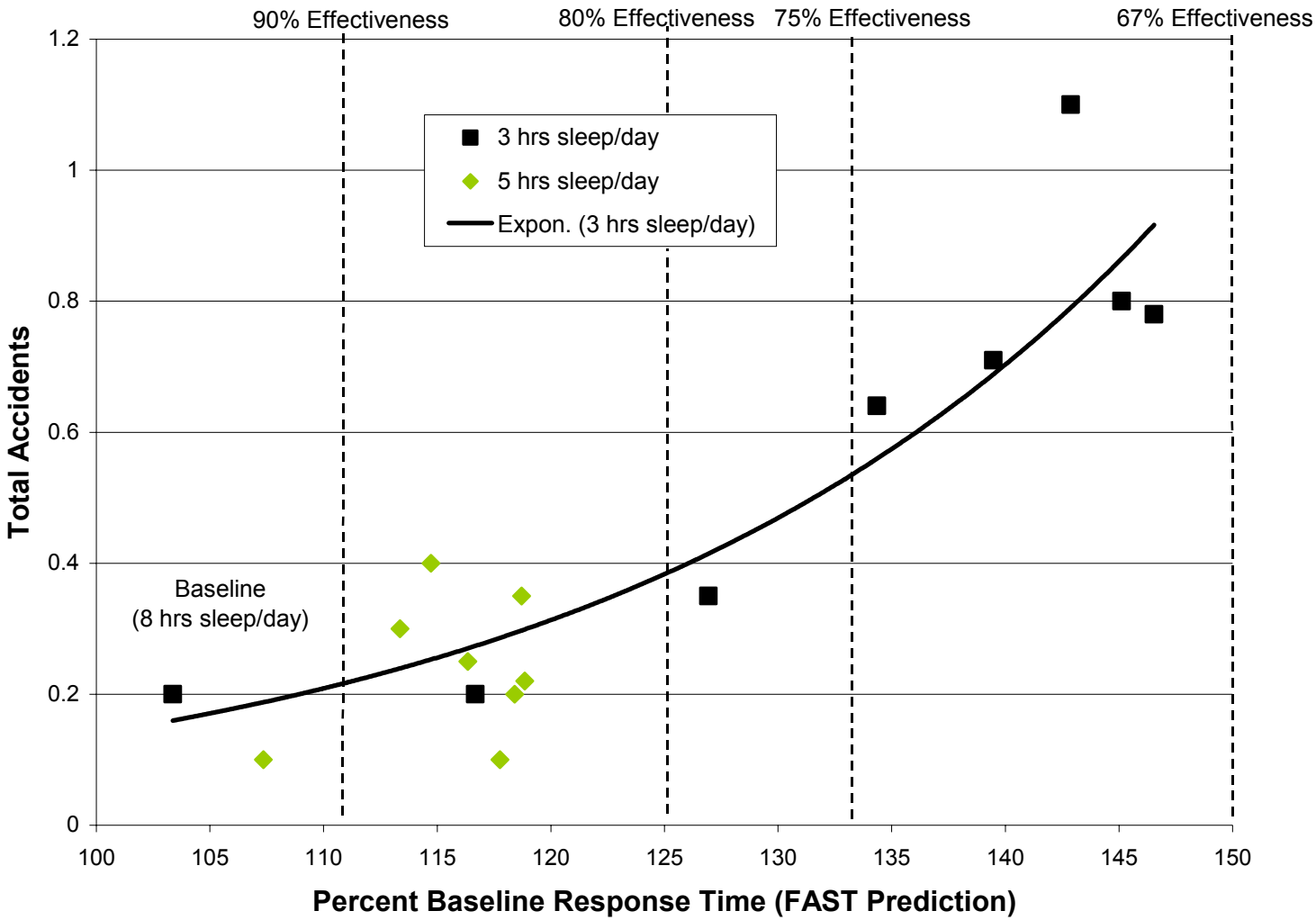


Figure 3.12. Hourly distribution of traffic accidents in Israel caused by falling asleep while driving for 6 consecutive years, 1984–1989, in comparison with hourly distribution of all traffic accidents for the same time period.

Driving Simulator Accidents

Limited Sleep Schedule Study (WRAIR Data)



The Sleep, Activity, Fatigue and Task Effectiveness Model (SAFTE™)

- *Description:* Model/simulation of how time of day (circadian rhythms) and sleep/wake patterns influence cognitive capacity and risk of performance error.
- *Purpose:* Part of fatigue management system to anticipate worker fatigue,optimize schedules to reduce risk of error, and improve operator safety, effectiveness, and quality of life.
- ***Benefit:*** **Summarizes the major observations from research and extends them to real world problems, based on a valid and patented model.**

Lineage of SAFTE Model

- ✓ AURA Sleep Module (1989) - BRL (Terry Klopsic)
- ✓ FORTRAN Sleep Model (1993) - SAIC/WRAIR (Hursh & McNally)
- ✓ Sleep and Performance Model (1996) - SAIC/WRAIR (Hursh)
- ✓ Sleep and Performance Simulation for IUSS (1997) - SAIC/Natick (Hursh)
- ✓ SAFTE Model (1998, 1999, 2000) - SAIC/ Brooks AFB (Hursh)

Government Experience

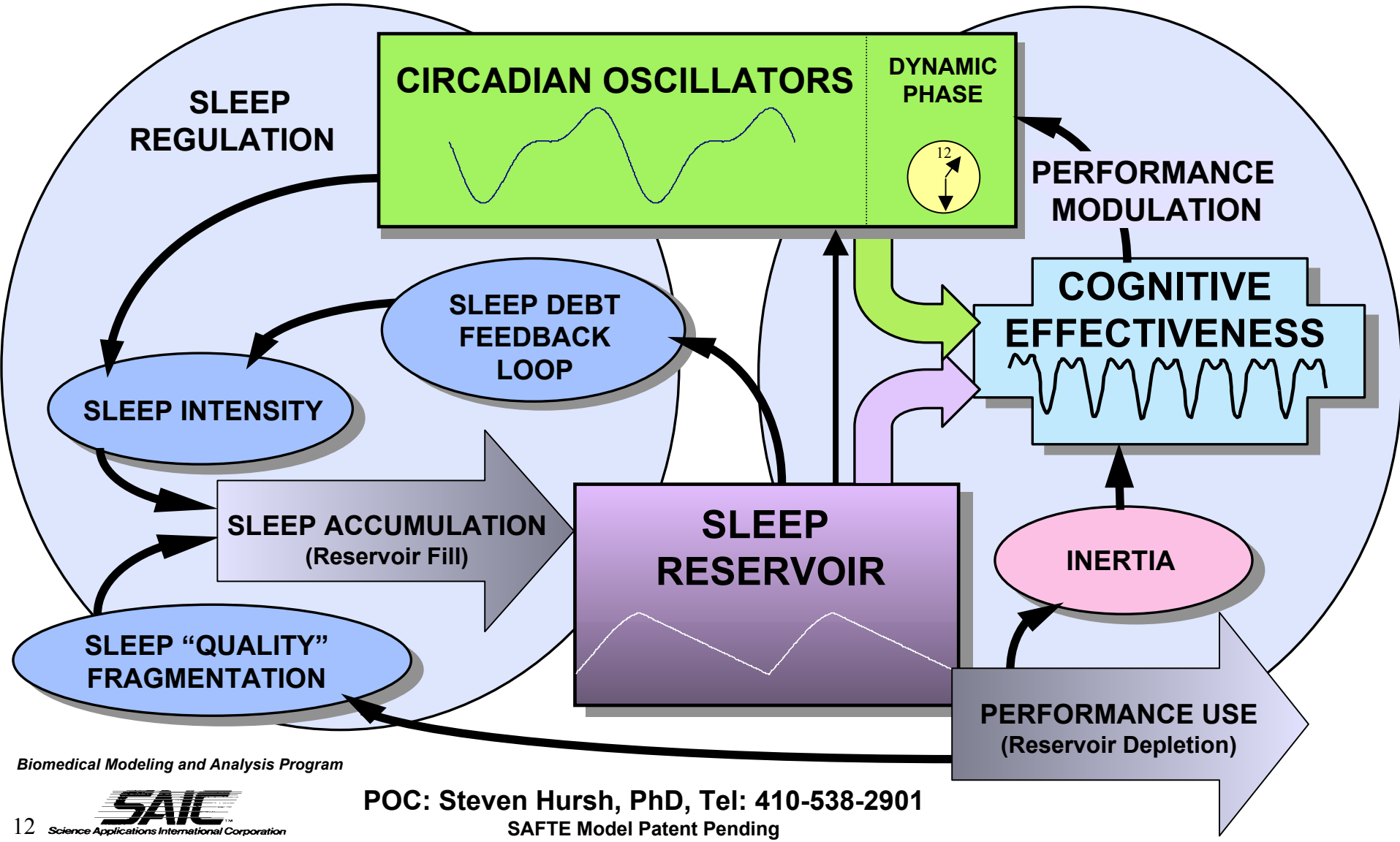
- US Army
  - ✓ Supported initial development of fatigue model
  - ✓ Continued support for specialized applications
- US Air Force
  - ✓ Approximately $1M investment for scheduling tool
  - ✓ Fatigue Avoidance Scheduling Tool (***FAST***™) user testing
- US Navy & US Marines
  - ✓ Testing alternative watch standing schedules
  - ✓ Applications for scheduling special operations
- Federal Railroad Administration
  - ✓ Current contract for schedule evaluation and safety analysis
  - ✓ Potential expansion to other transportation modes

SAFTE/*FAST* Development Team

- Air Force Research Laboratory, Brooks AFB
  - ✓ Dr. William Storm
  - ✓ Dr. James C. Miller
  - ✓ CAPT William Hurtle
- Walter Reed Army Institute of Research
  - ✓ COL Gregory Belenky
  - ✓ Dr. Thomas Balkin
  - ✓ COL Daniel Redmond
- Federal Railroad Administration
  - ✓ Dr. Thomas Raslear
  - ✓ Michael Coplen
- NTI, Inc.
  - ✓ Dr. Douglas Eddy
  - ✓ Dr. Timothy Elsmore
- SAIC
  - ✓ Dr. Steven Hursh

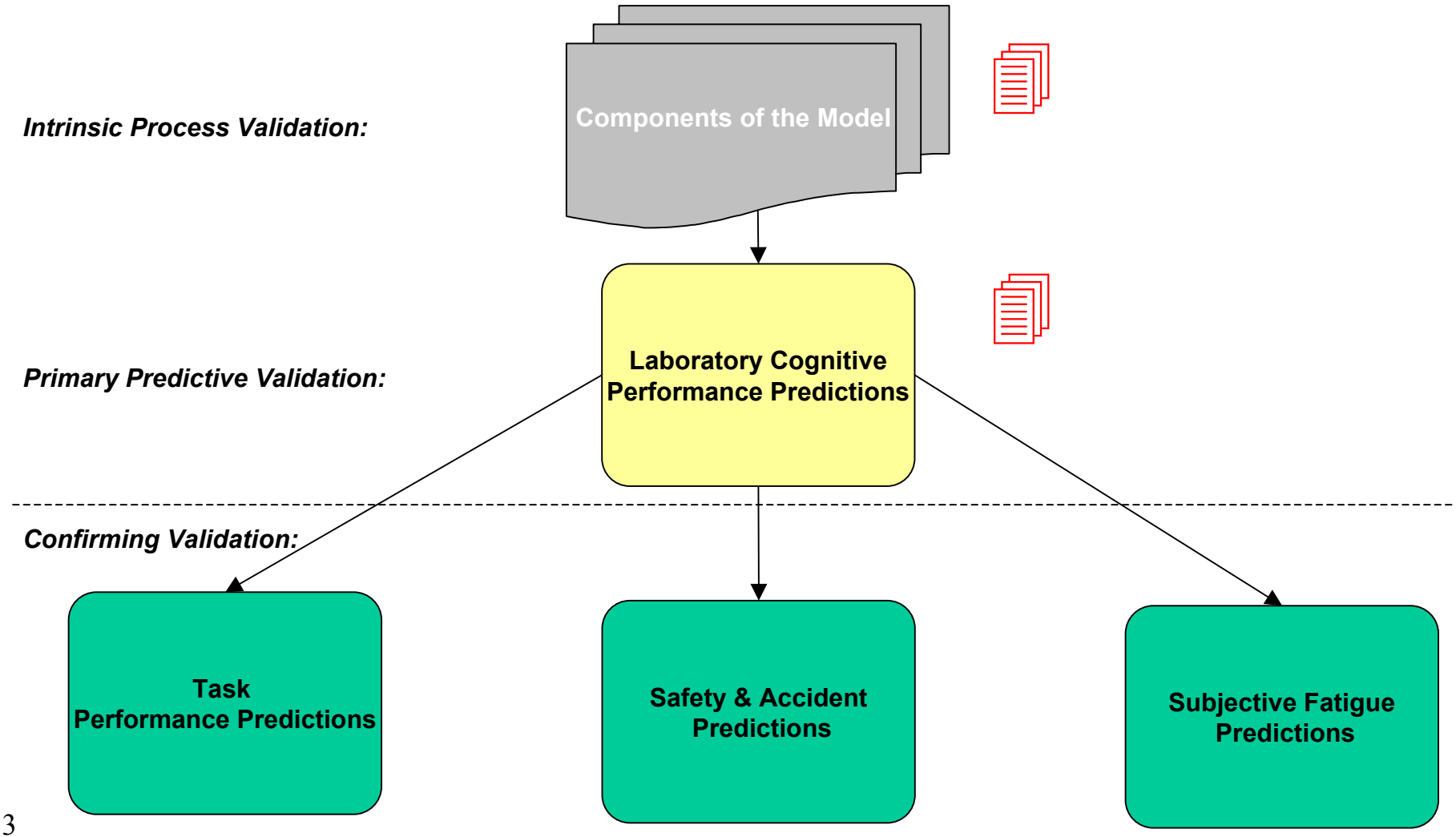
Schematic of SAFTE™ Simulation Model

Sleep, Activity, Fatigue and Task Effectiveness Model



POC: Steven Hursh, PhD, Tel: 410-538-2901

Validation of SAFTE Model



To be carried out under Federal Railroad Administration approved project

CIRCADIAN RHYTHM OF CORE TEMPERATURE AND SUBJECTIVE ALERTNESS

(Monk & Embrey, 1981)

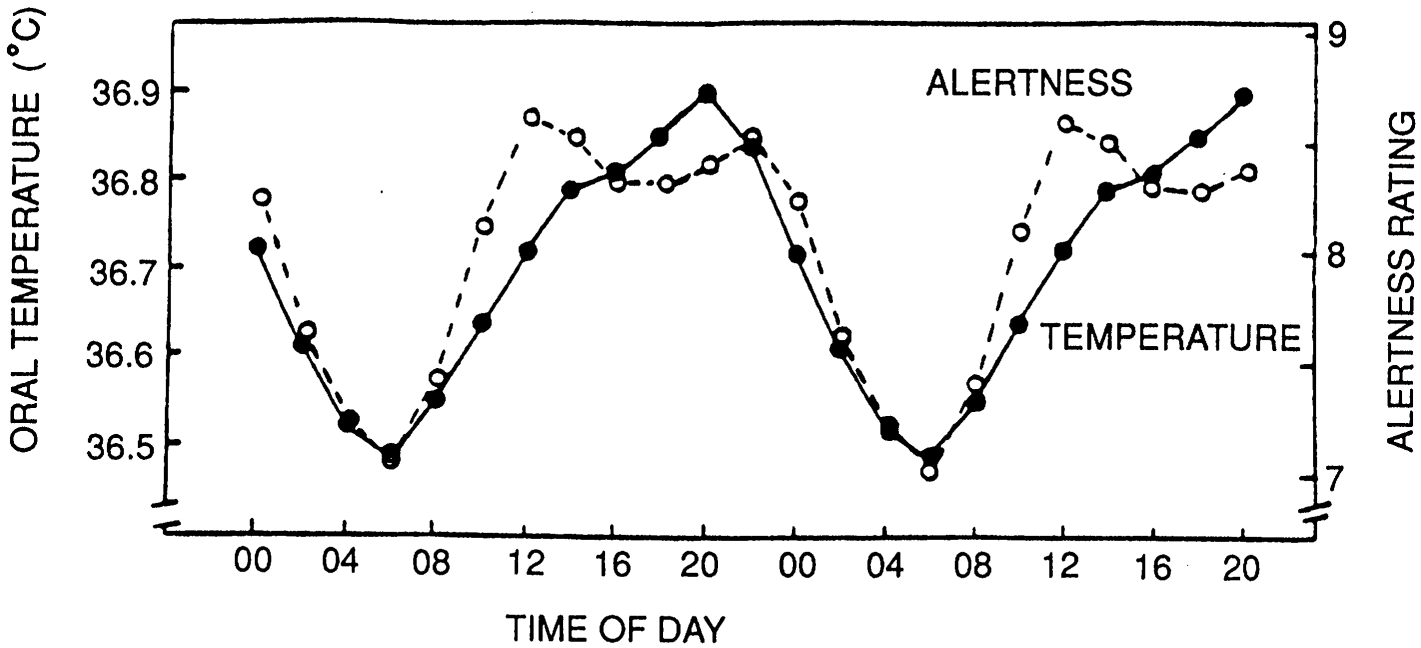
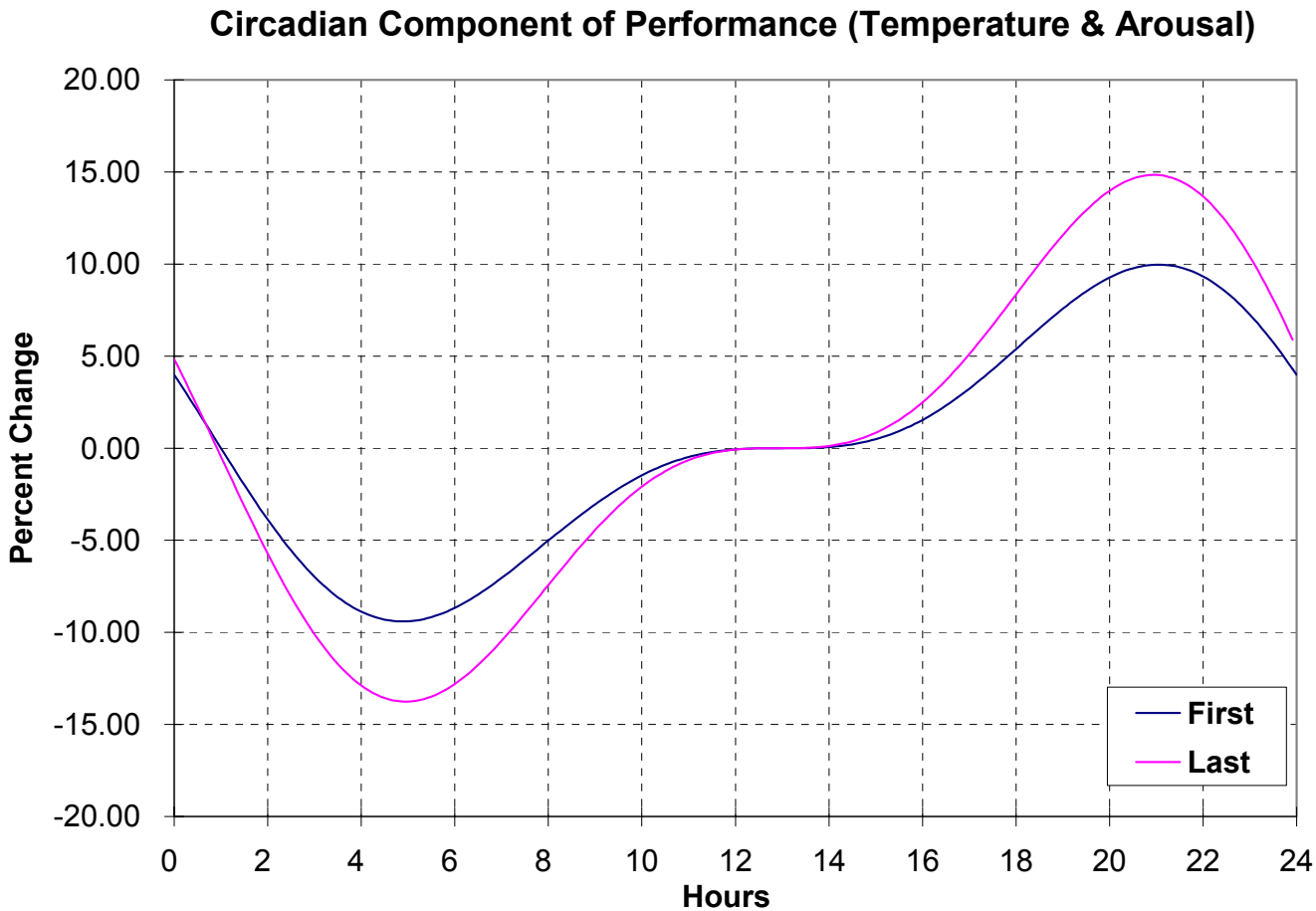


Figure 2.10. Circadian rhythms in oral temperature (●—●) subjective alertness (o—o) from six rapidly rotating shift workers, each studied for a month. Two cycles of the 12 points defining each rhythm have been plotted (after Monk and Embrey, 1981). Reprinted by permission of Pergamon Press PLC.

Symmetrical Multi-Oscillator Circadian Rhythm
Neutral Parameter Model

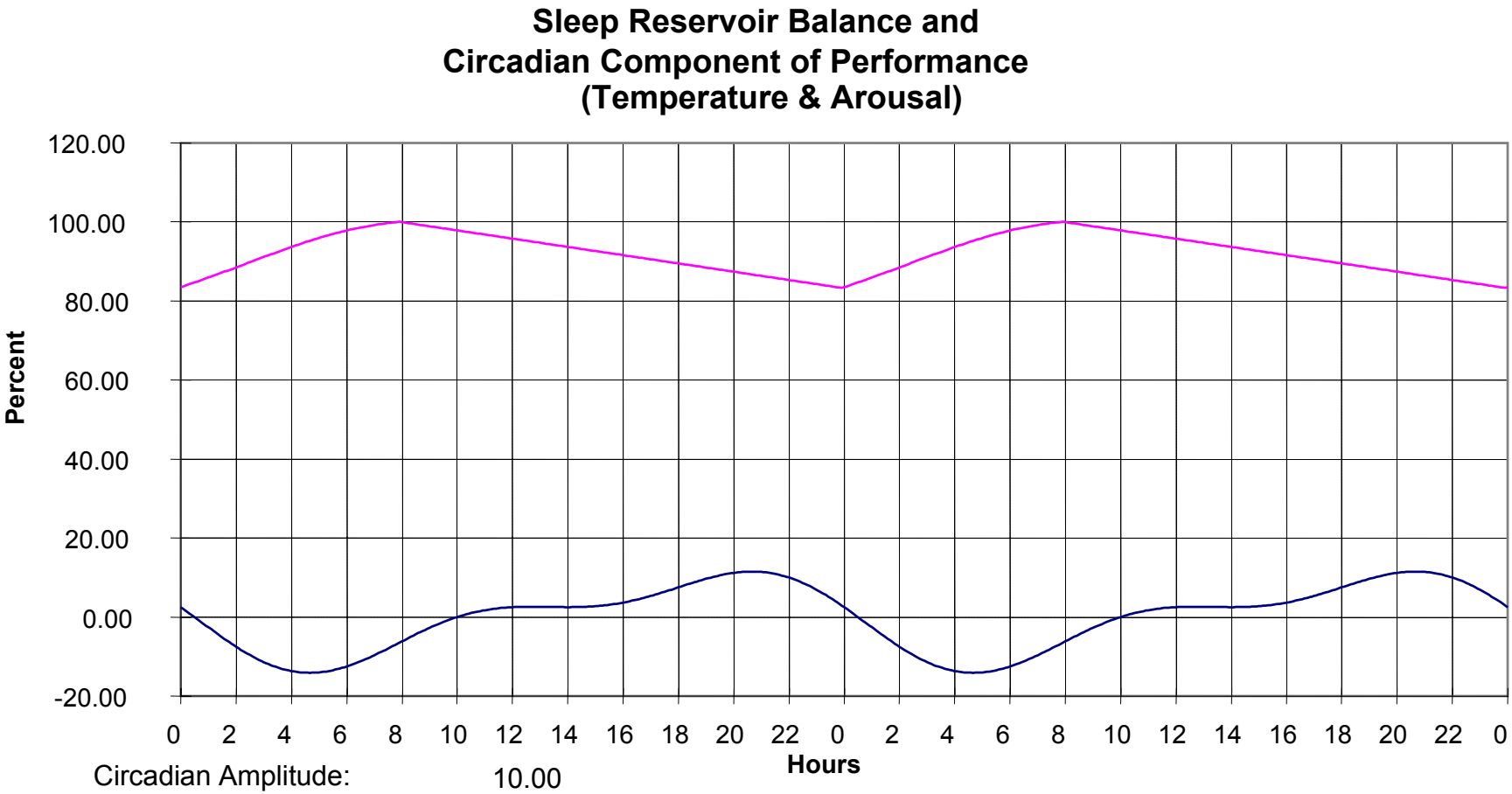
Plateau is approximately mid-cycle: 1300 hrs for a person sleeping 0000 to 0800
Note Amplitude Increase after 72 hrs Sleep Deprivation



Circadian Amplitude: 7

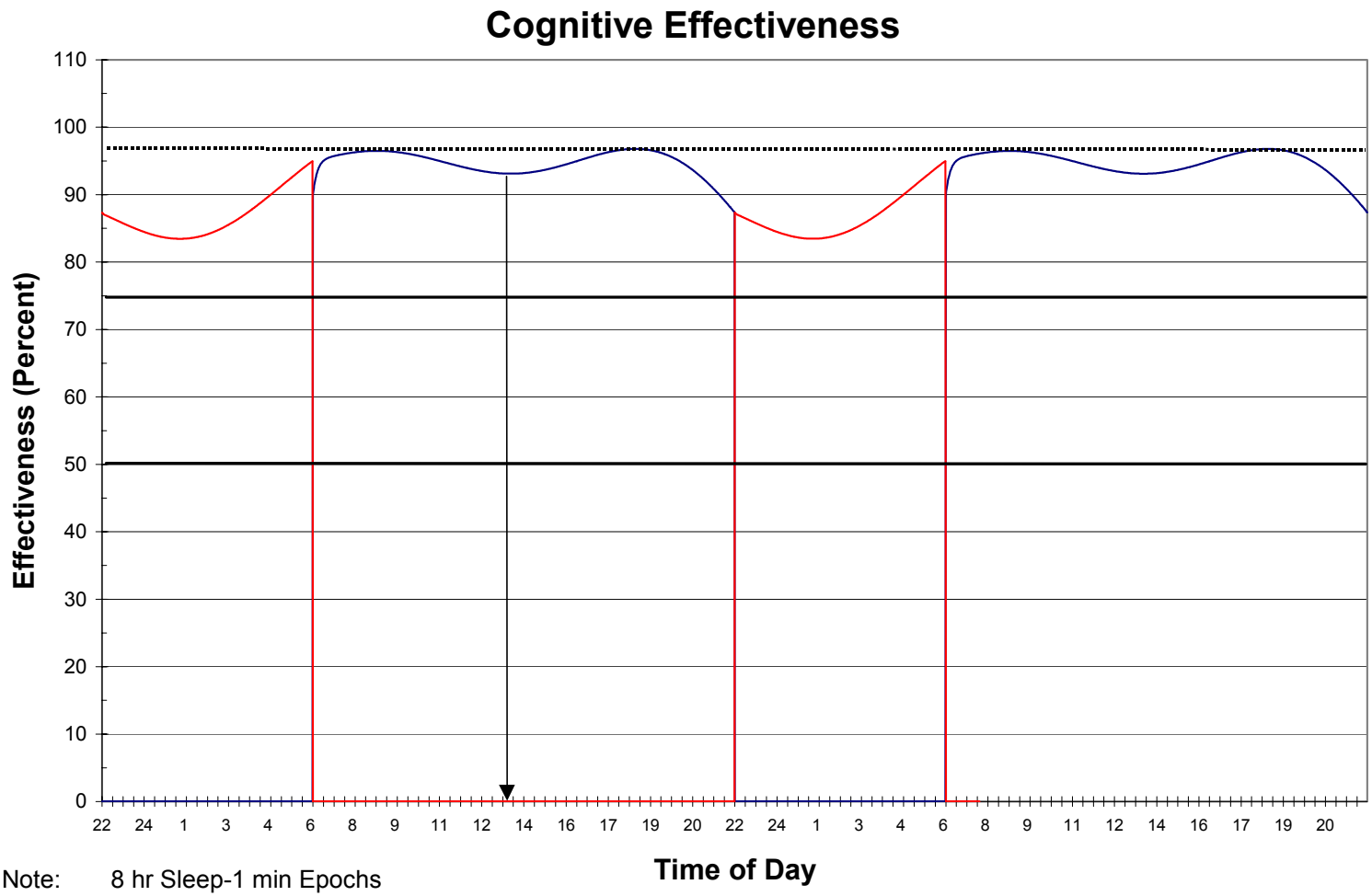
TWO MAJOR COMPONENTS OF PERFORMANCE

SLEEP RESERVOIR BALANCE (SWC) AND CIRCADIAN RHYTHM OF ALERTNESS



Each function is scaled in comparable units of percent of baseline performance.

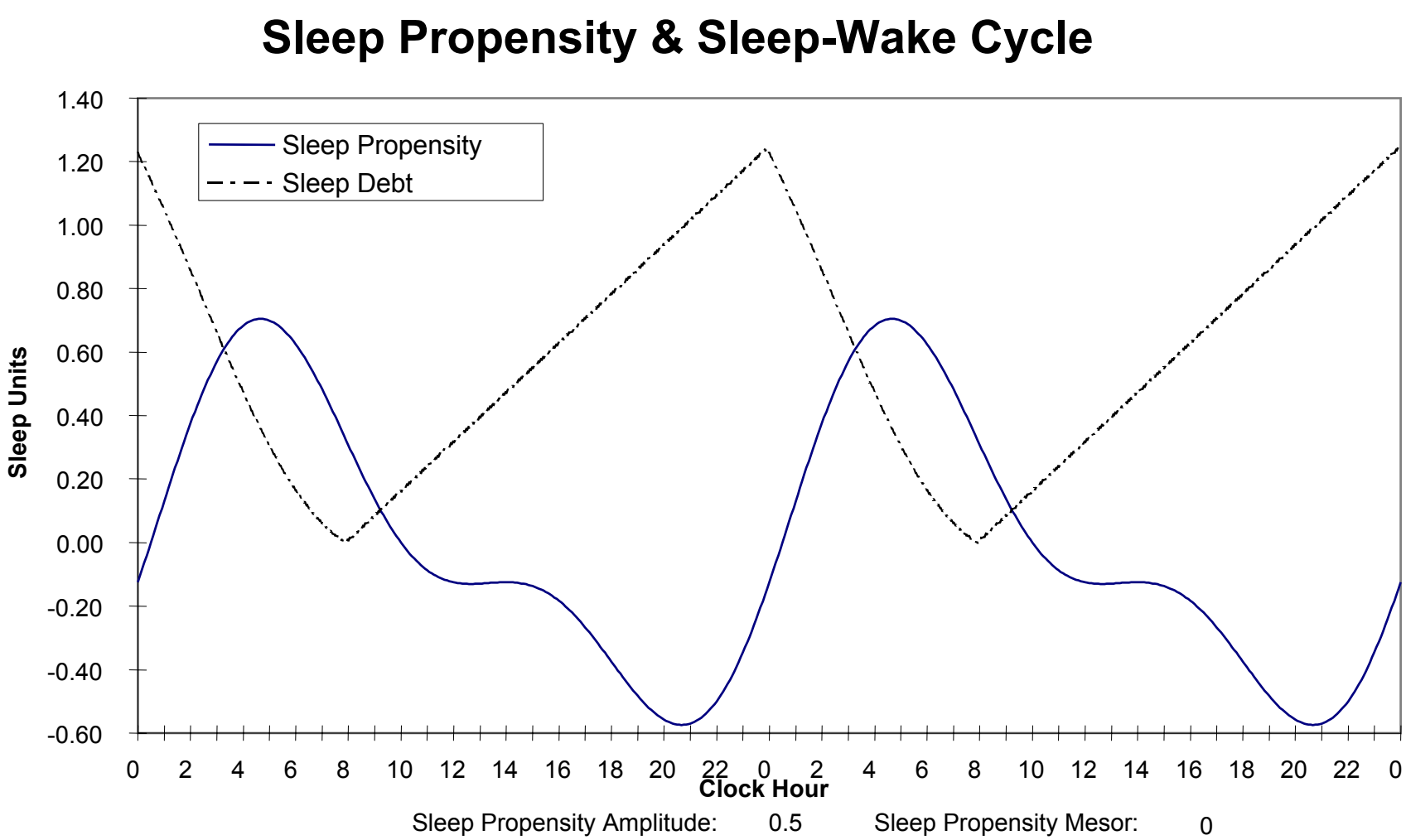
Typical Performance Prediction with 8 hrs Sleep from 2200 to 0600 hrs



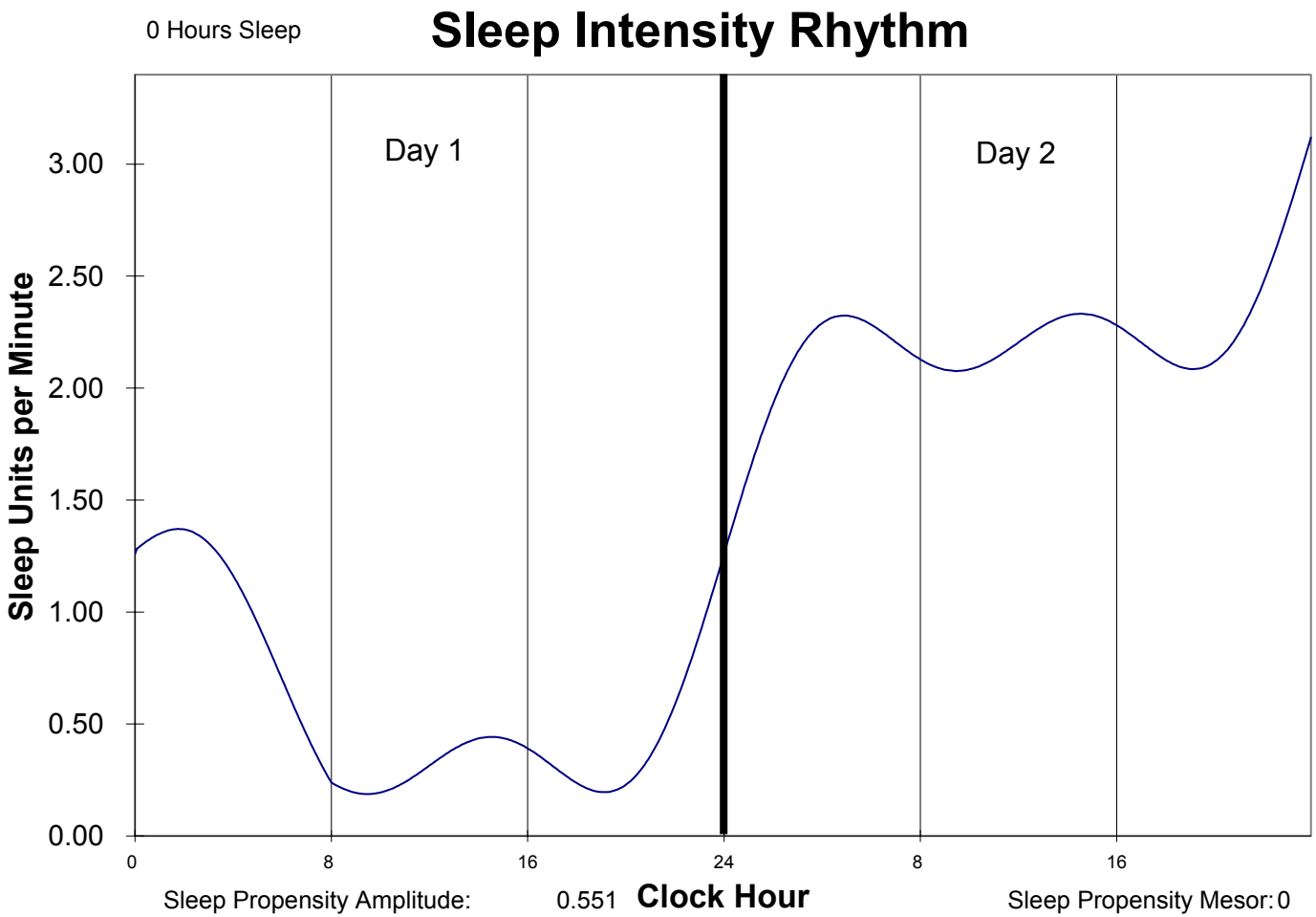
Note: 8 hr Sleep-1 min Epochs

TWO DRIVERS OF "SLEEPINESS"

Sleep Propensity and Sleep Debt (Sleep-Wake Cycle)

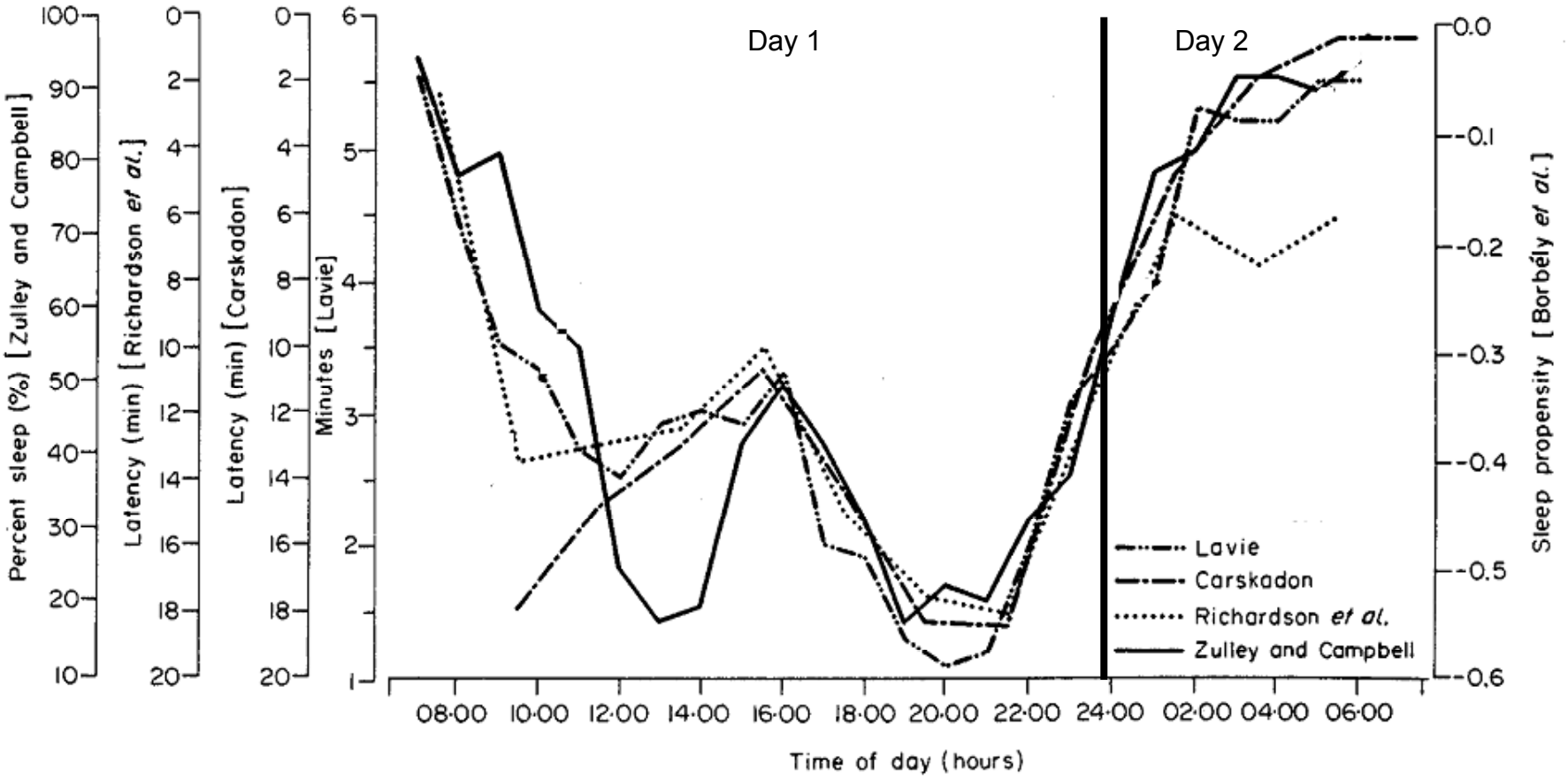


MODEL OF VARIATIONS IN "SLEEPINESS"



COMPARISON OF "SLEEPINESS" TEST RESULTS

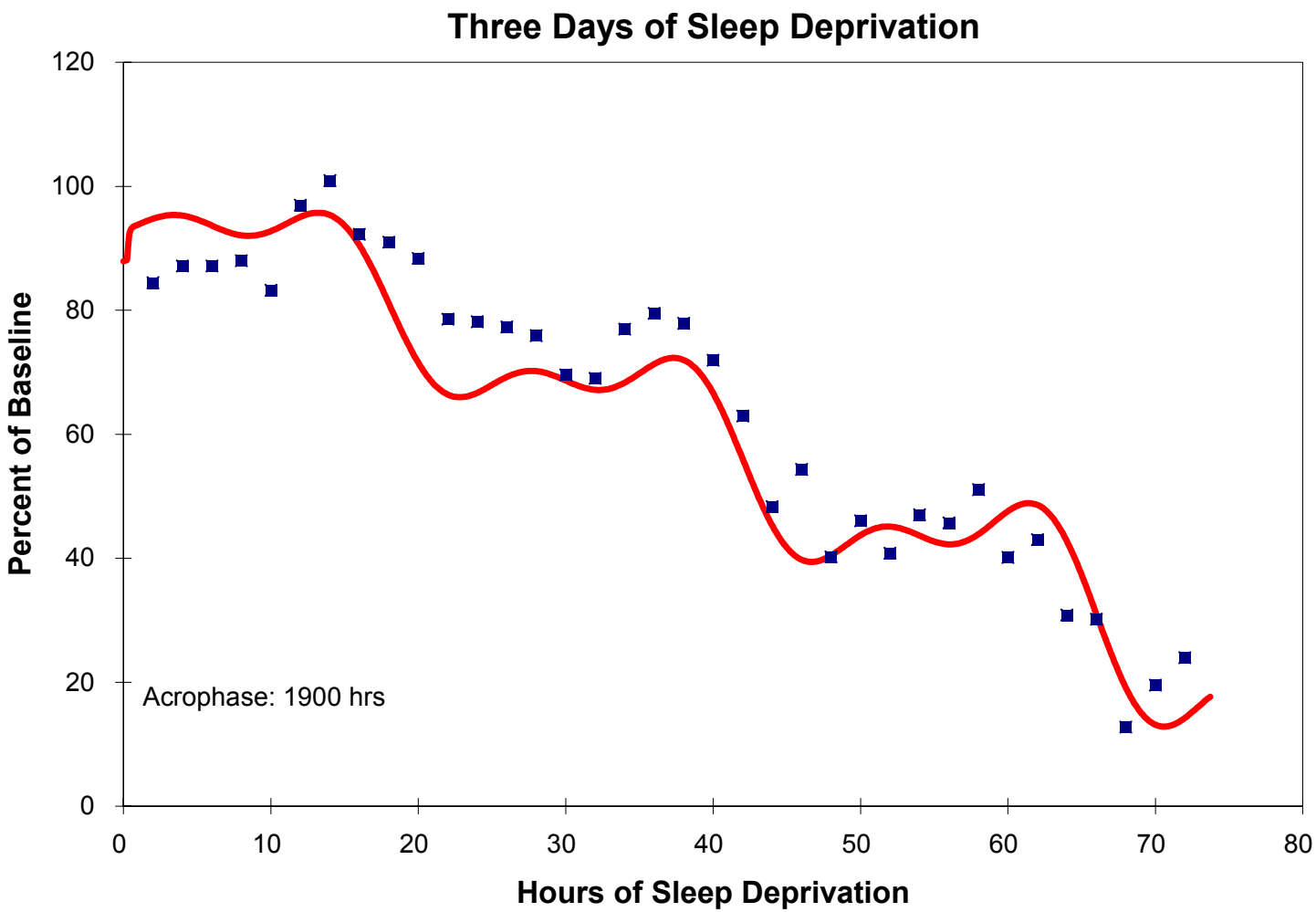
Broughton and Mullington (1992)



SAFTE MODEL

Predictions and Data for Total Sleep Deprivation

(WRAIR 72 hr Study)

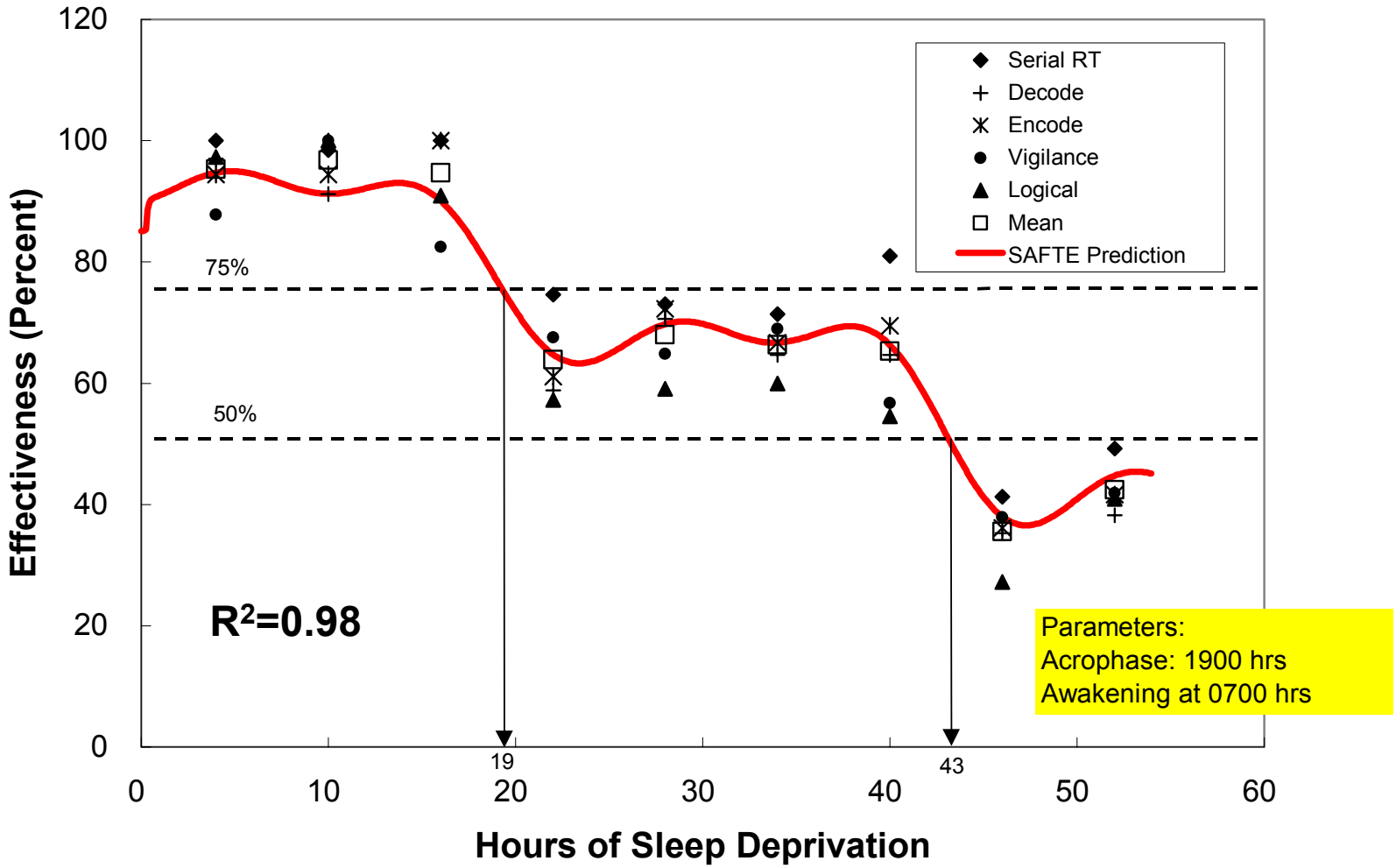


Decline of Performance with Total Sleep Deprivation

SAFTE Model (red line) Predicts the Average Results with Precision

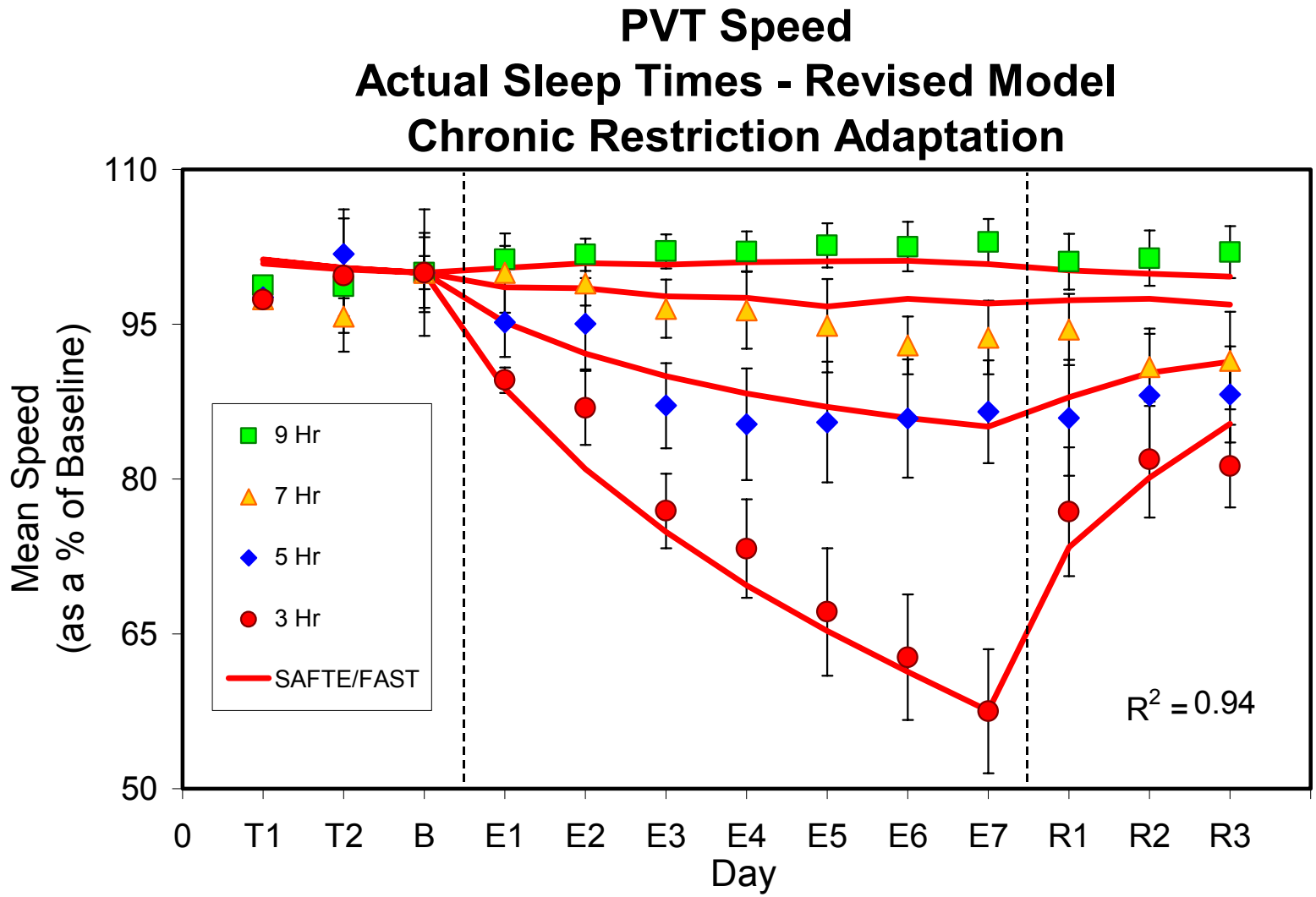
Sleep & Performance Model *vs* Angus & Heslegrave (1985)

Mean of Normalized Performance Measures



Walter Reed Restricted Sleep Study

SAFTE Model (red line) Predicts the Average Results with Precision



The SAFTE Model "Best in the World"

- The DOD sponsored a recent comparison of six fatigue models from around the world.
- All models attempted to predict the results from four standard scenarios.
- **The SAFTE model had less error than any model tested and was combined with a convenient and logical user interface, the fatigue avoidance scheduling tool - *FAST*.**

What Can Be Done to Avoid Fatigue?

Fatigue Countermeasures

- Planning for eight hours of sleep per day at optimal time
- Conducive sleep environment: dark, quiet, comfortable
- 30 min to 3 hr strategic naps
- Regular recovery sleep following long duty days
- Circadian adjustments for night-shift workers
- Caffeine, with caution
- Procedural Safeguards: Check-lists, co-worker double-checks, and enhanced monitoring
- Integration of fatigue assessment into safety programs

Schedule Evaluation Tools

- Fatigue management tools are required for:
  - ✓The improvement of work schedules
  - ✓Training of effective rest habits - ”life style” decisions
  - ✓Isolation of fatigue related events
  - ✓Planning for the use of mitigations and countermeasures
  - ✓Staffing analysis and workforce planning

Fatigue Risk Management Tools

- ***FAST*** ™ – Fatigue Avoidance Scheduling Tool
  - ✓ Prospective forecasting of fatigue risk under proposed work/rest schedules.
  - ✓ Retrospective assessment of fatigue leading up to an event.
  - ✓ Uses the SAFTE model of fatigue developed by the DOD.
- **IFAP**™ – Incident Fatigue Assessment Protocol
  - ✓ Questionnaire and schedule assessment software to aid event analysis.
  - ✓ Integrates data into FAST for fatigue assessment.
- ***FAST-MAN*** ™ - FAST for Management
  - ✓ Access database system for multiple personnel work schedules
  - ✓ Rapid assessment program for work force evaluation
  - ✓ Cross-walk to database of safety related errors and rules violations

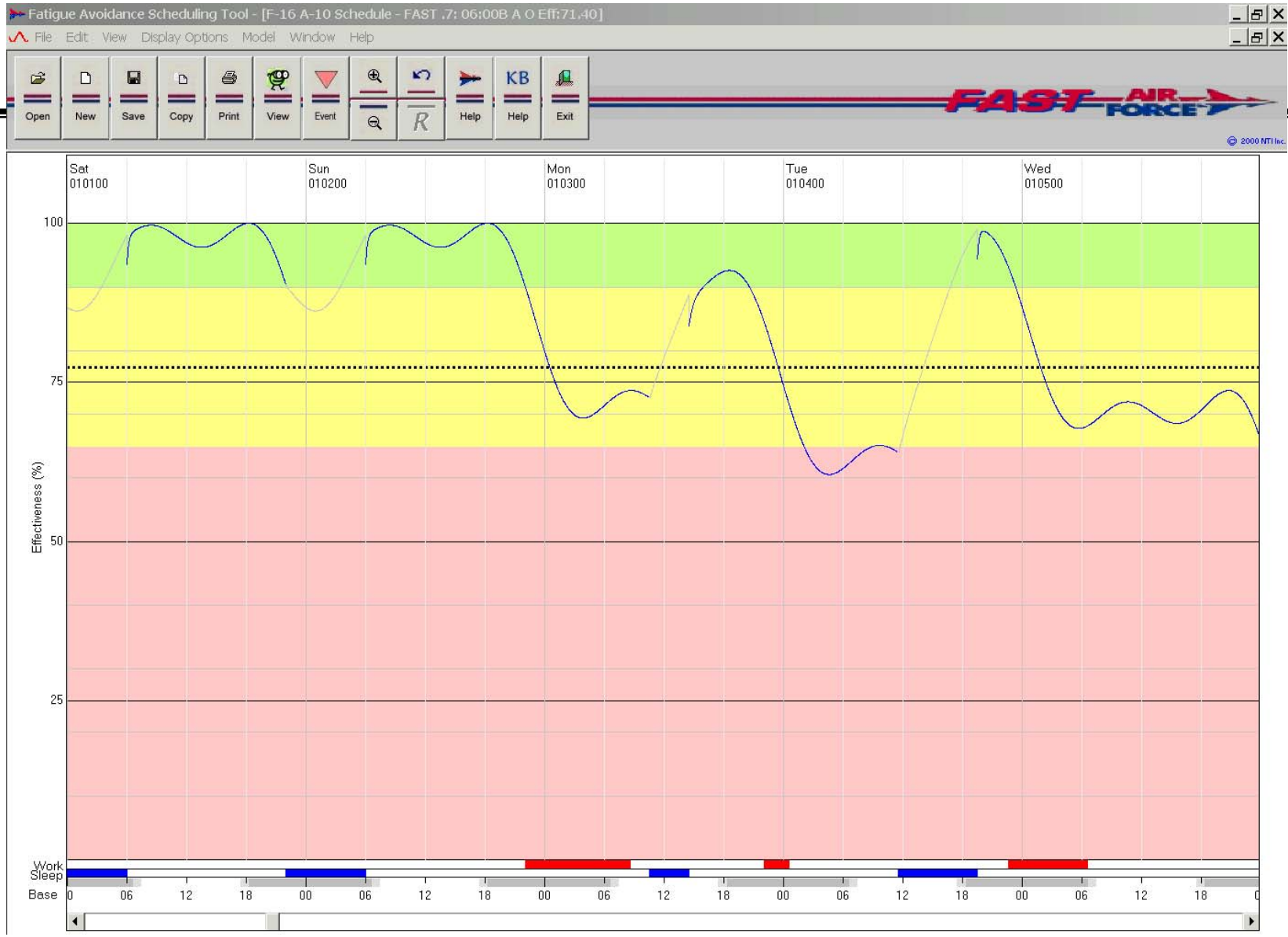
Fatigue Avoidance Scheduling Tool (*FAST*™)

- ***FAST***™ is a fatigue assessment tool based on the SAFTE™ model
- Developed for the US Air Force and the US Army.
- NTI and SAIC completing a Phase II SBIR program.
- DOT/FRA sponsored work has lead to a transportation specific version.
- DOT field validations underway.

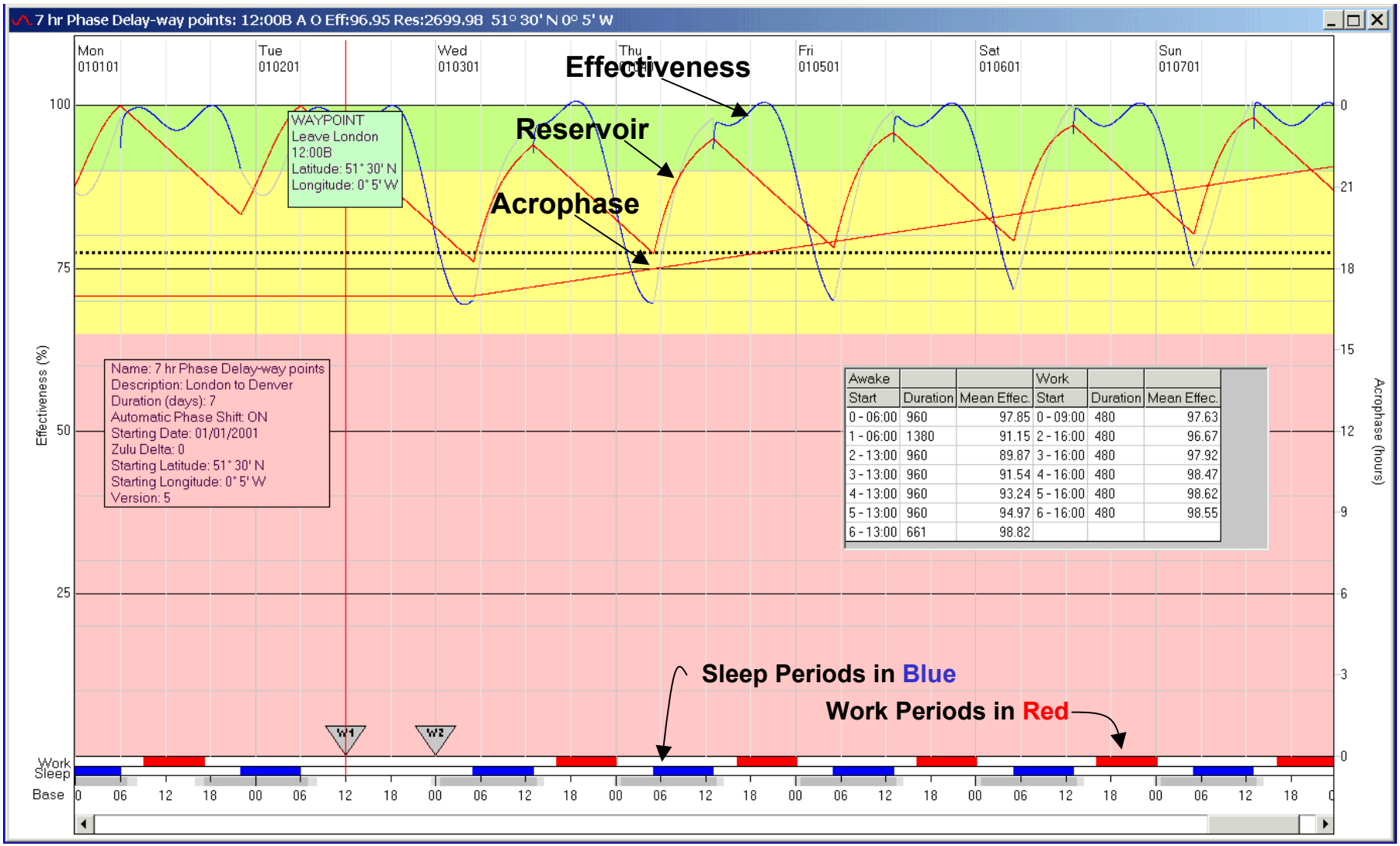
Overview of *FAST-TR* ™

Example of Commercial Application

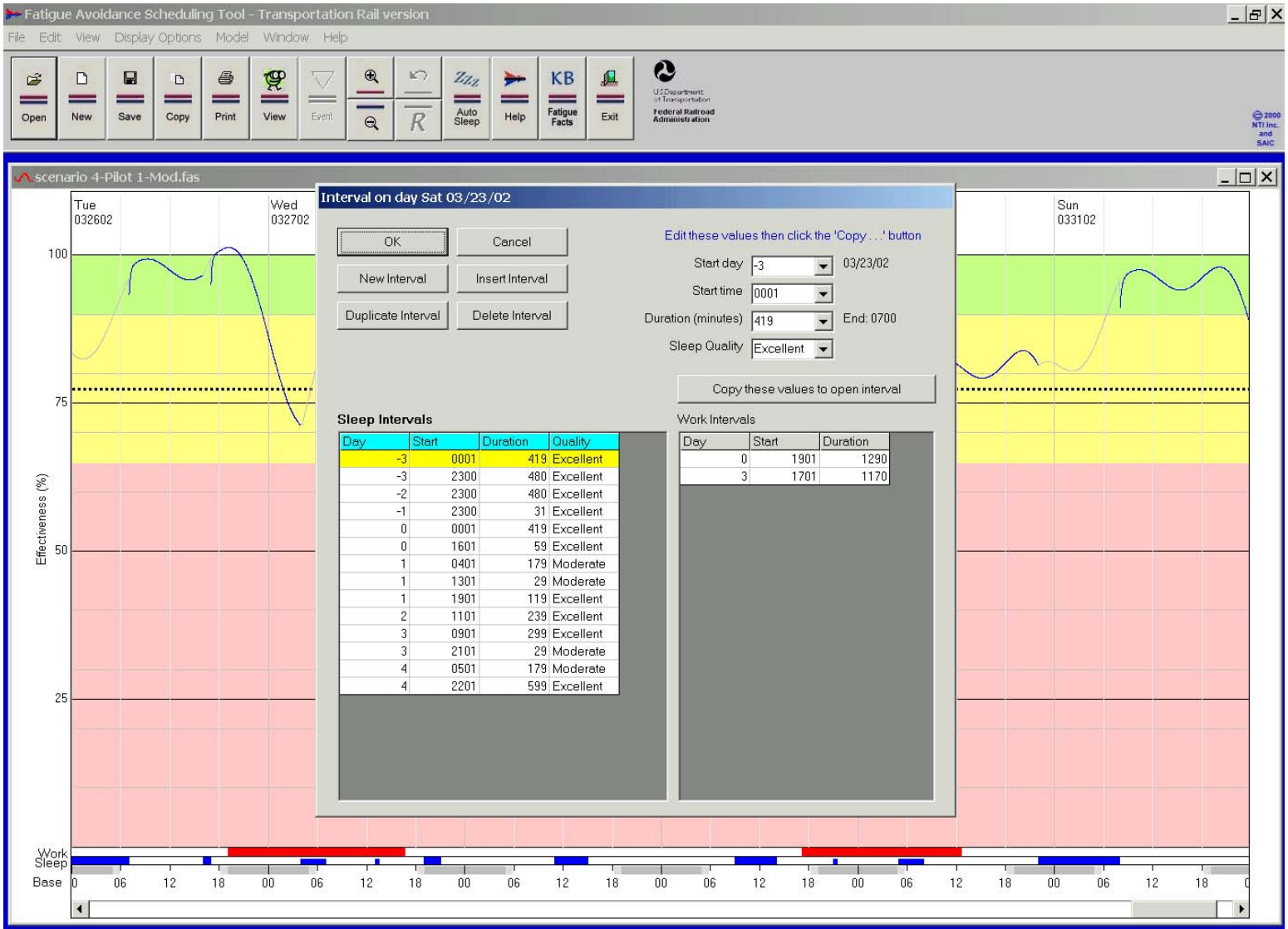
- ***FAST-TR*** ™ is designed to serve as a schedule evaluation and accident investigation tool in a single software package for use by the railroad industry.
- Refine prediction with information on actual sleep or special circumstances.
- Based on ***FAST*** ™, the Air Force tool
- Transportation version uses a two-step estimation process:
  1. Estimate sleep pattern based on work schedule
  2. Estimate performance effectiveness based on sleep pattern


Fatigue Avoidance Scheduling Tool - [F-16 A-10 Schedule - FAST .7: 06:00B A O Eff:71.40]
File Edit View Display Options Model Window Help
Open New Save Copy Print View Event Help Help Exit
FAST AIR FORCE
© 2000 NTI Inc.
Sat 010100
Sun 010200
Mon 010300
Tue 010400
Wed 010500
100
75
50
25
Effectiveness (%)
Work
Sleep
Base
0 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18 00 06 12 18

FAST-TR Graphical Screen Options



FAST-TR Schedule Entry Options

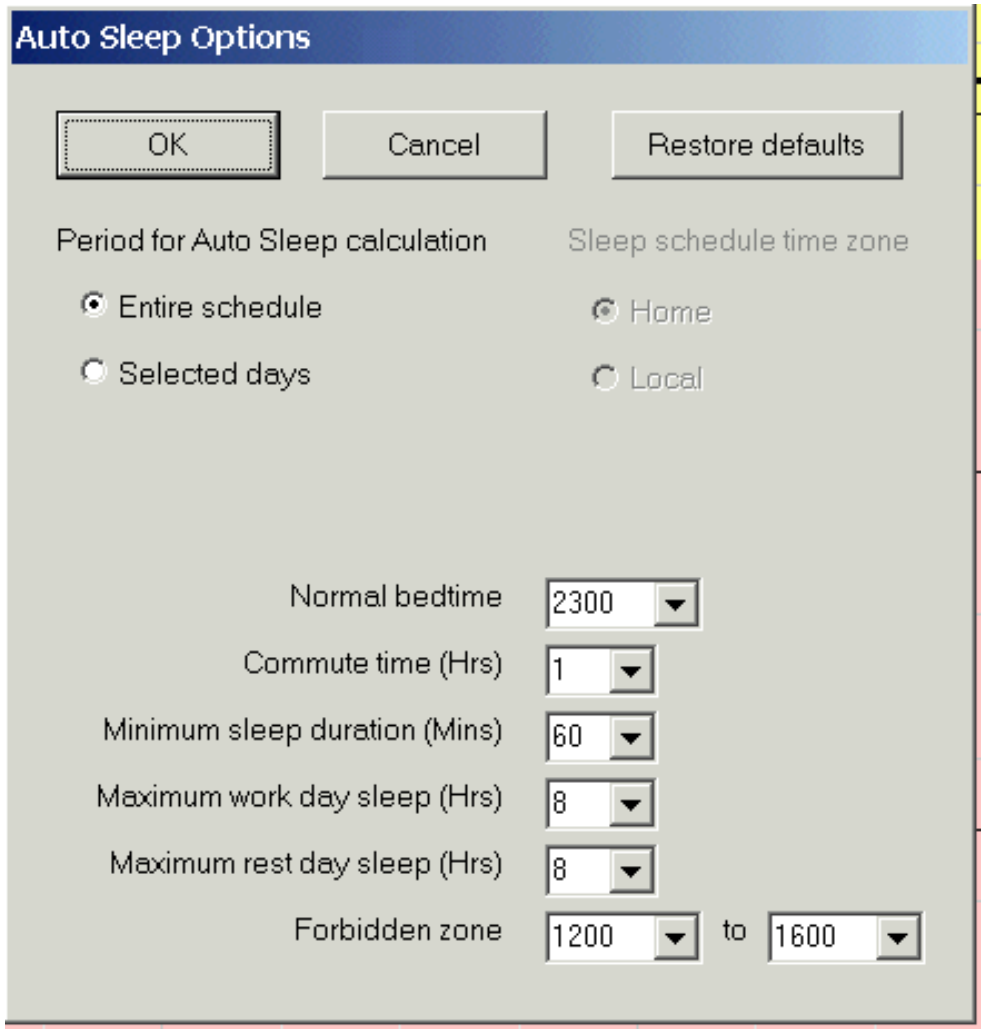


FAST-TR™

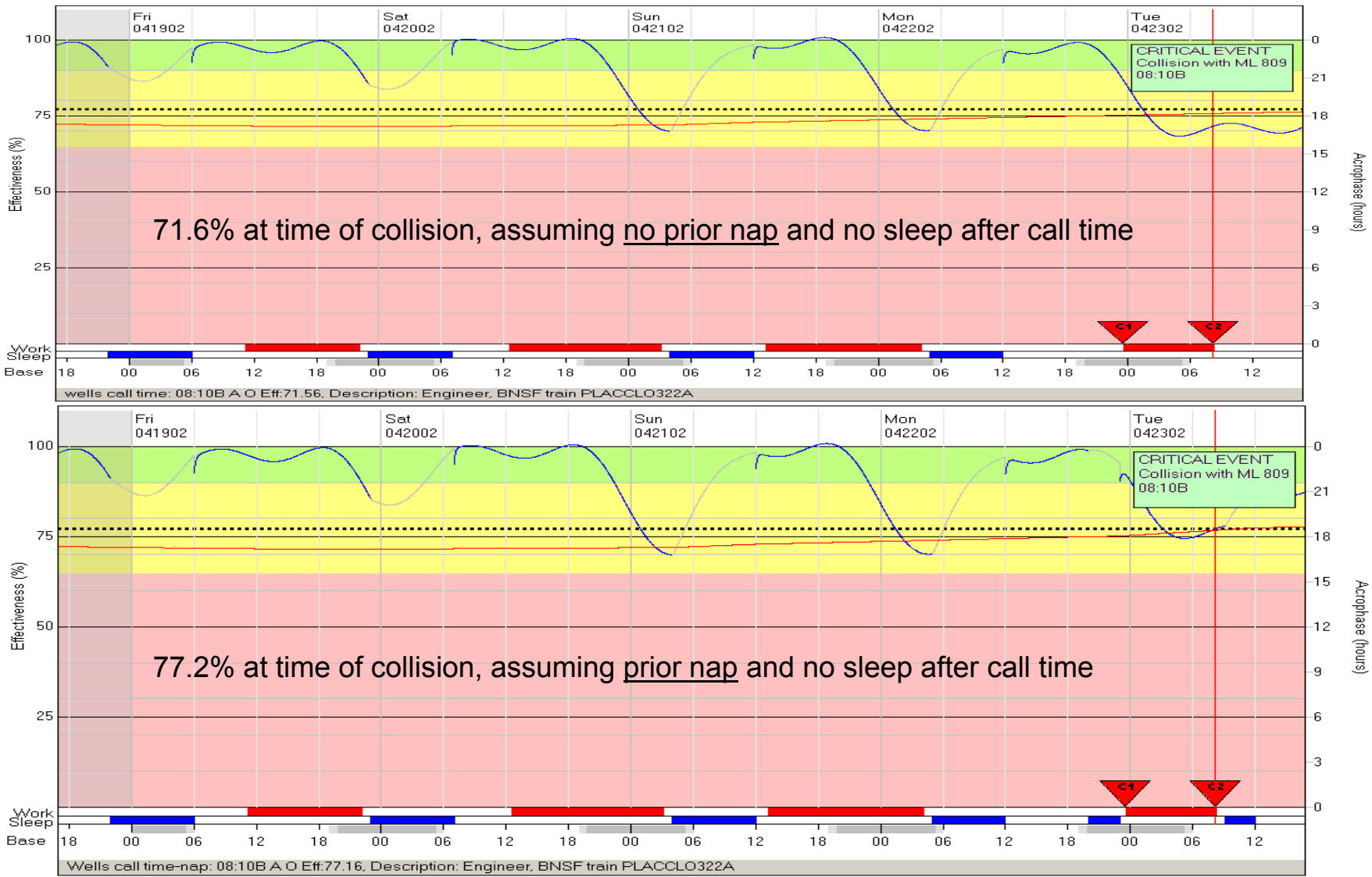
AutoSleep Sleep Generator

- Based on the work schedule alone ***FAST-TR***™ can generate a reasonable sleep schedule.
- ***FAST-TR***™ sleep pattern estimation methodology is called **AutoSleep**. It calculates a reasonable pattern of normal sleep to accompany a work schedule entered by the user.
- The pattern of sleep can be tailored to specific habits of the individual or may be set to mimic the average pattern of railroad engineers (see Pollard, 1996).
- **AutoSleep can be used to estimate sleep patterns under irregular work schedules typical of rail operations or to estimate sleep patterns under regular or rotating shift-schedules.**

Optional AutoSleep Input



Freight Engineer Effectiveness
Sleep Pattern Estimated with AutoSleep



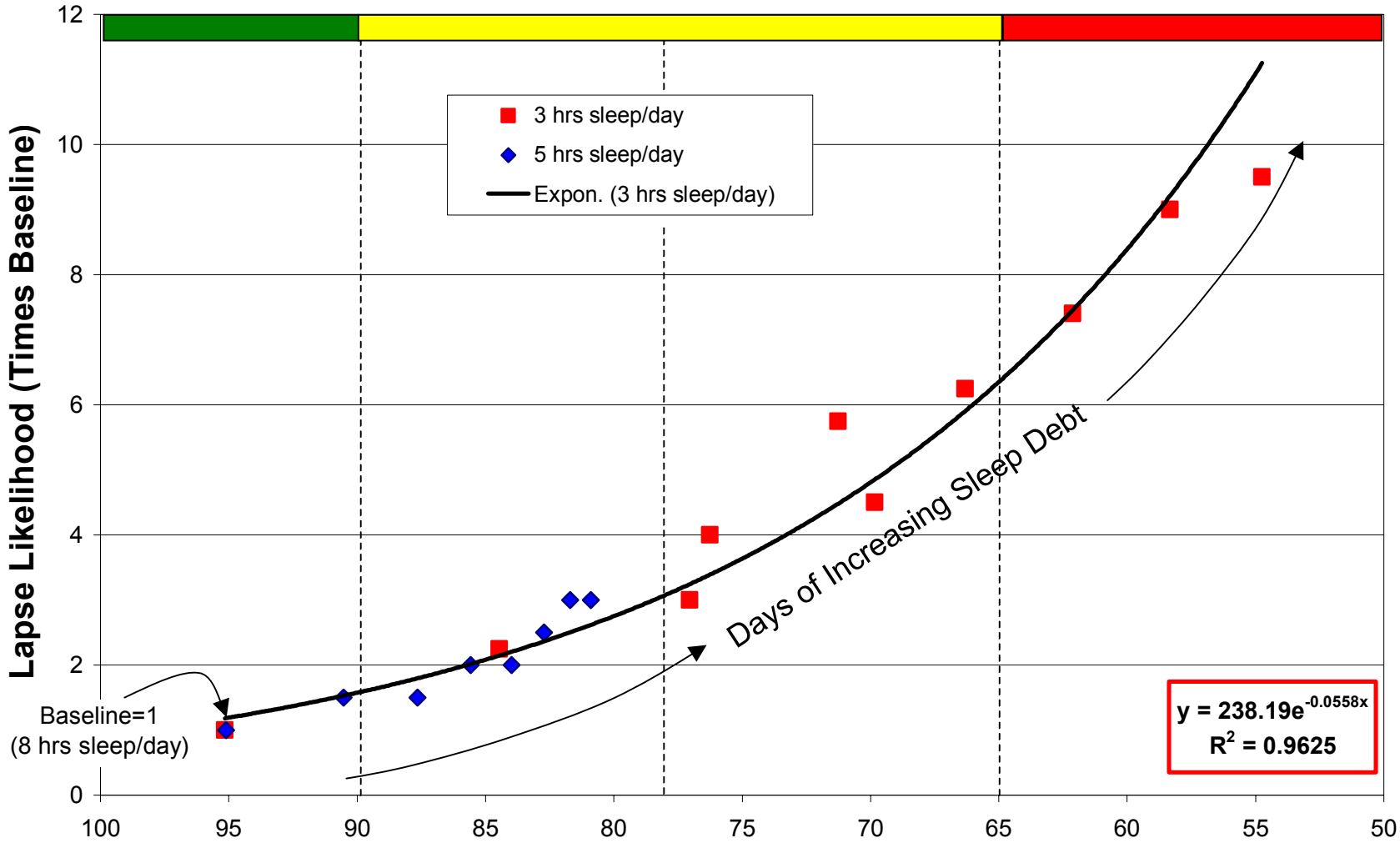
SAFTE Model and *FAST* tool Predict Increases in Accident Related Lapses

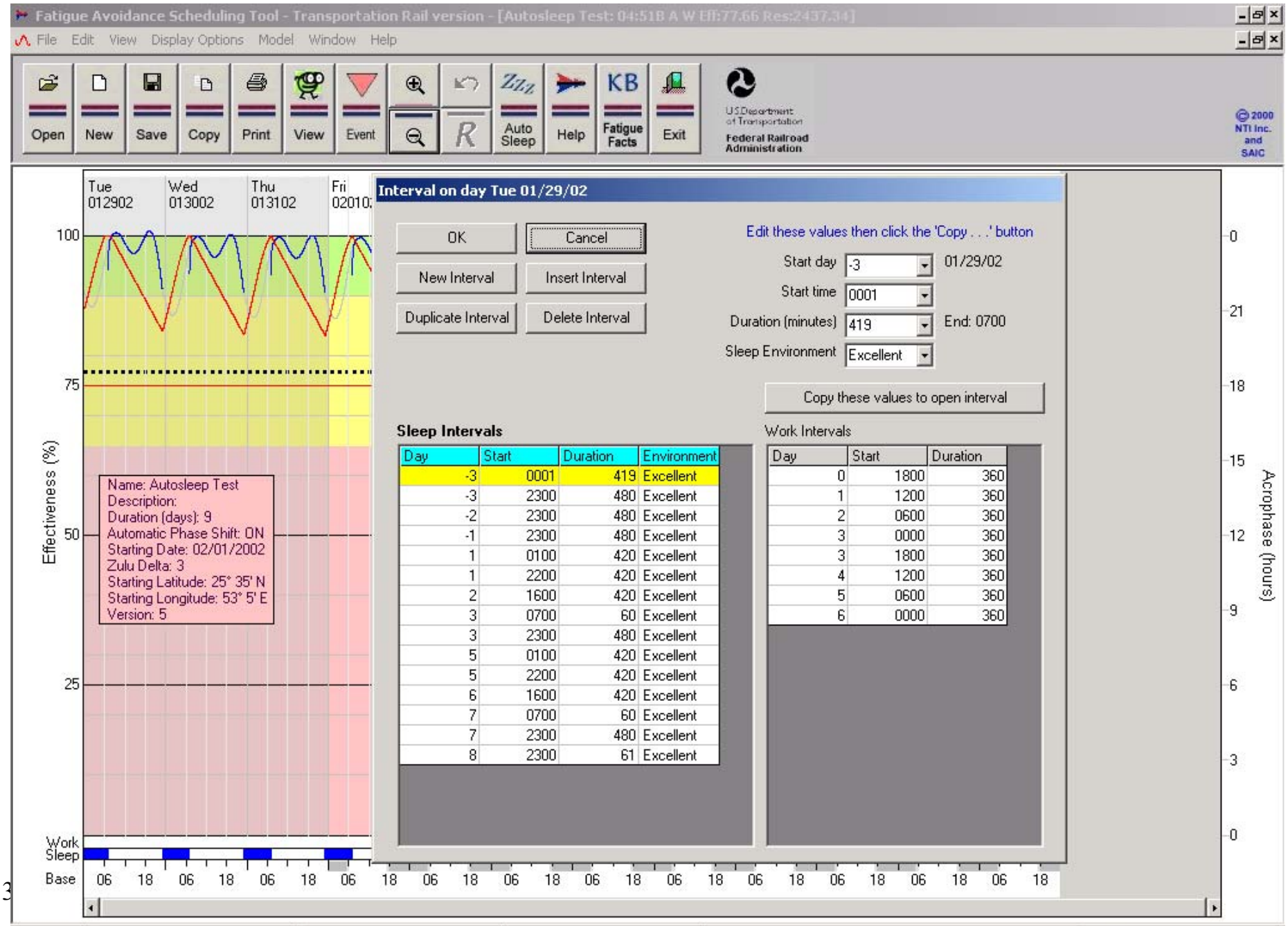
- Effectiveness is a measure of speed of making correct responses.
- Lapses increase dramatically with decreasing effectiveness (see next chart).
- Reduced effectiveness can predict errors resulting from on-the-job lapses associated with excessive fatigue.
- **Low levels of effectiveness can be used to implicate fatigue as a possible contributing factor to human factors incidents and accidents.**

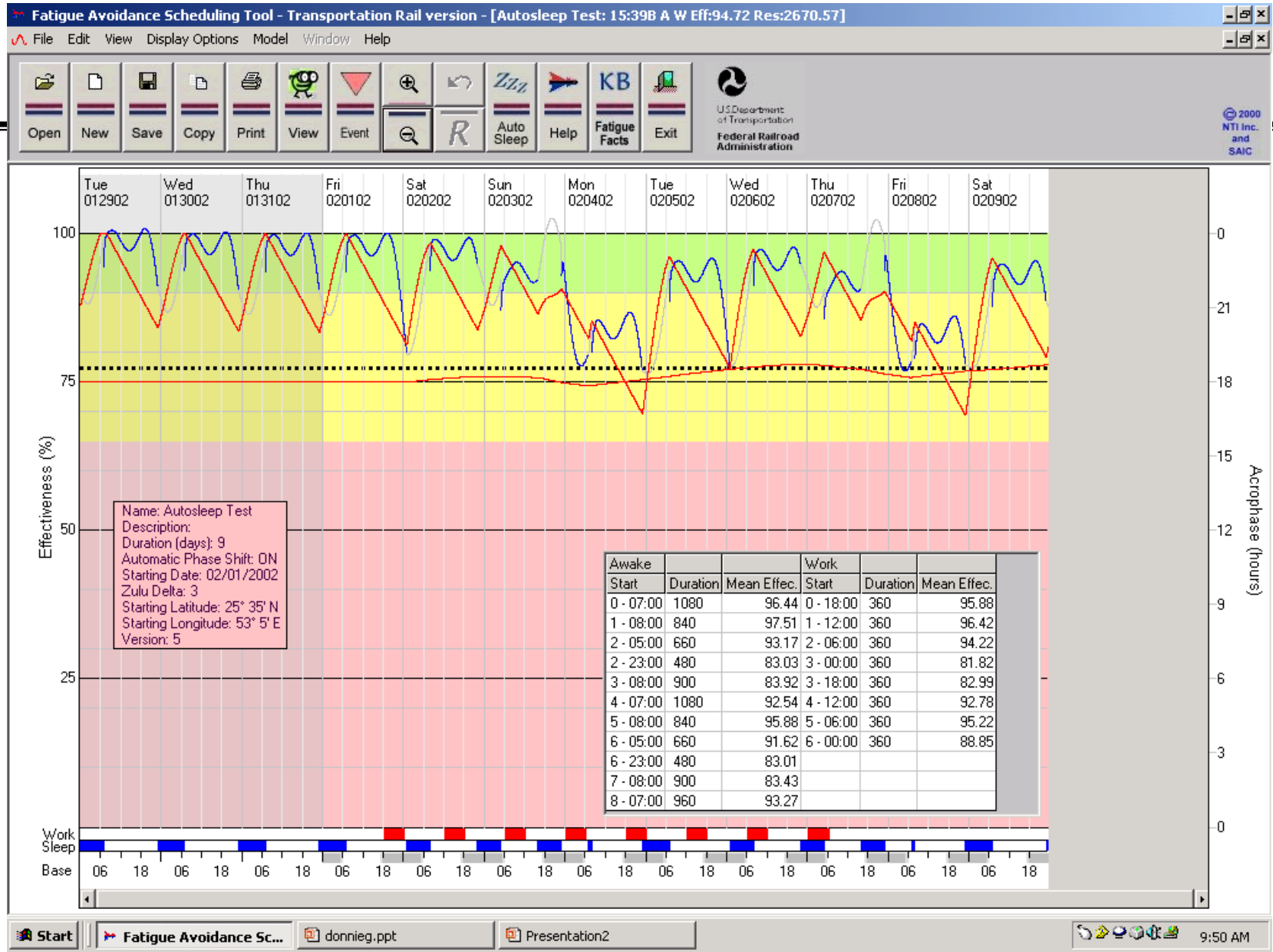
Lapses Increase with Decreasing Effectiveness

from *FAST* (revised)

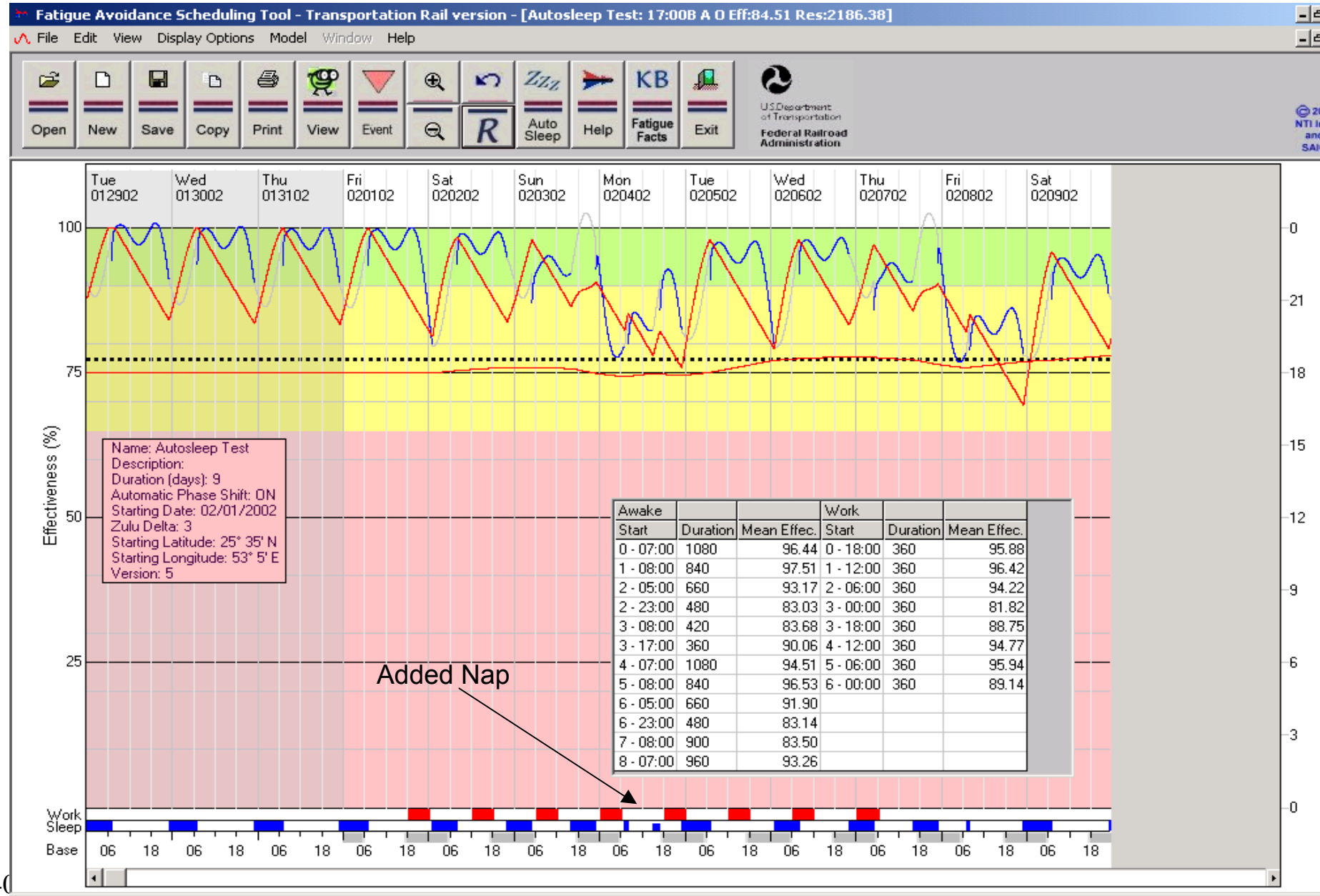
Sleep Dose Response Study – Experimental & Recovery Days - WRAIR Data




Fatigue Avoidance Scheduling Tool - Transportation Rail version - [Autosleep Test: 04:51B A W Eff:77.66 Res:2437.34]
File Edit View Display Options Model Window Help
Open New Save Copy Print View Event Auto Sleep Help Fatigue Facts Exit
U.S.Department of Transportation
Federal Railroad Administration
© 2000 NTI Inc. and SAIC
Tue 012902
Wed 013002
Thu 013102
Fri 02010
Interval on day Tue 01/29/02
OK
Cancel
New Interval
Insert Interval
Duplicate Interval
Delete Interval
Edit these values then click the 'Copy . . .' button
Start day -3 01/29/02
Start time 0001
Duration (minutes) 419 End: 0700
Sleep Environment Excellent
Copy these values to open interval
Sleep Intervals
Day Start Duration Environment
-3 0001 419 Excellent
-3 2300 480 Excellent
-2 2300 480 Excellent
-1 2300 480 Excellent
1 0100 420 Excellent
1 2200 420 Excellent
2 1600 420 Excellent
3 0700 60 Excellent
3 2300 480 Excellent
5 0100 420 Excellent
5 2200 420 Excellent
6 1600 420 Excellent
7 0700 60 Excellent
7 2300 480 Excellent
8 2300 61 Excellent
Work Intervals
Day Start Duration
0 1800 360
1 1200 360
2 0600 360
3 0000 360
3 1800 360
4 1200 360
5 0600 360
6 0000 360
Name: Autosleep Test
Description:
Duration (days): 9
Automatic Phase Shift: ON
Starting Date: 02/01/2002
Zulu Delta: 3
Starting Latitude: 25° 35' N
Starting Longitude: 53° 5' E
Version: 5
Effectiveness (%)
100
75
50
25
Acrophase (hours)
0
21
18
15
12
9
6
3
0
Work
Sleep
Base
06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18 06 18



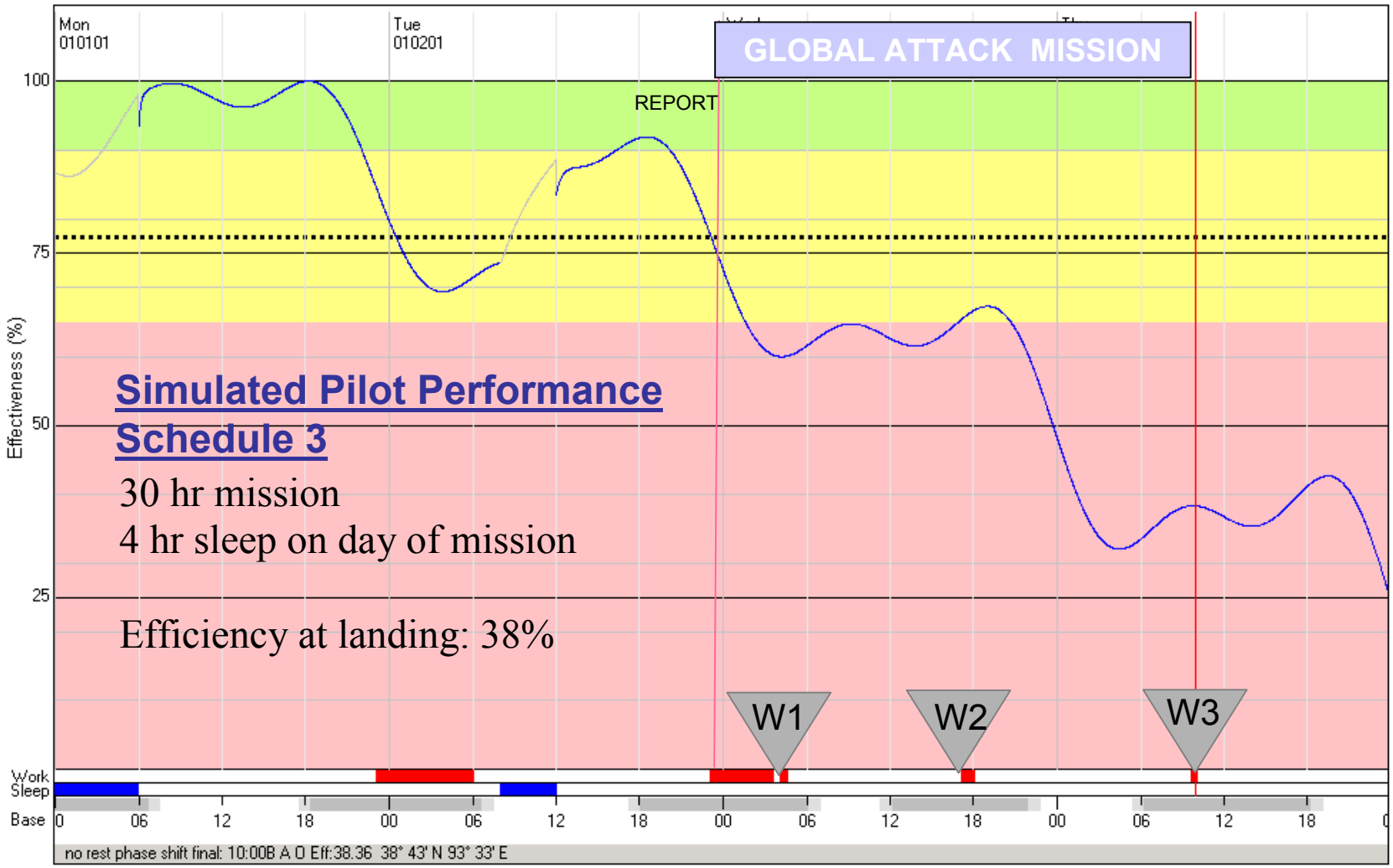
Awake			Work		
Start	Duration	Mean Effec.	Start	Duration	Mean Effec.
0 - 07:00	1080	96.44	0 - 18:00	360	95.88
1 - 08:00	840	97.51	1 - 12:00	360	96.42
2 - 05:00	660	93.17	2 - 06:00	360	94.22
2 - 23:00	480	83.03	3 - 00:00	360	81.82
3 - 08:00	900	83.92	3 - 18:00	360	82.99
4 - 07:00	1080	92.54	4 - 12:00	360	92.78
5 - 08:00	840	95.88	5 - 06:00	360	95.22
6 - 05:00	660	91.62	6 - 00:00	360	88.85
6 - 23:00	480	83.01			
7 - 08:00	900	83.43			
8 - 07:00	960	93.27			



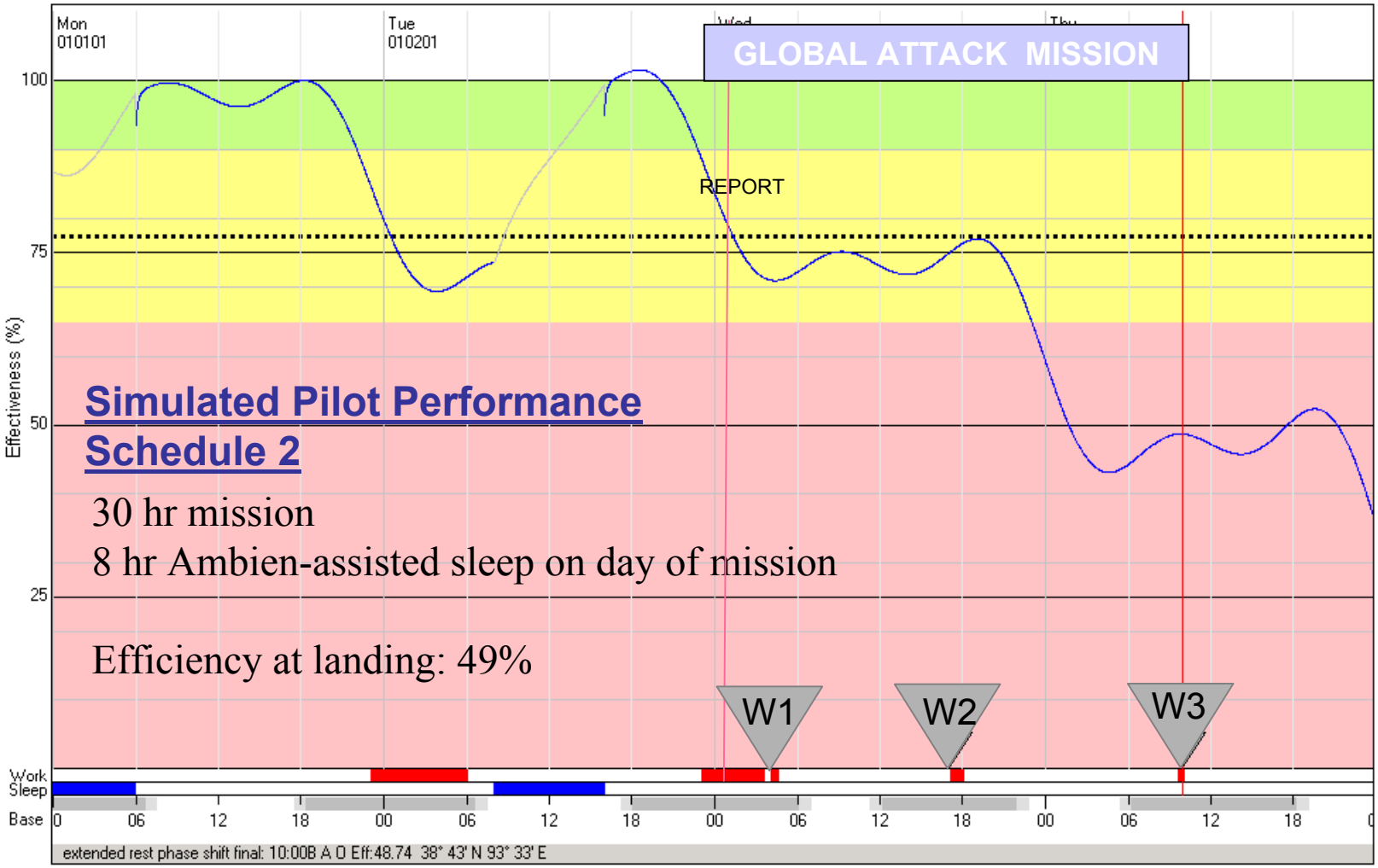
Awake Start	Duration	Mean Effec.	Work Start	Duration	Mean Effec.
0 - 07:00	1080	96.44	0 - 18:00	360	95.88
1 - 08:00	840	97.51	1 - 12:00	360	96.42
2 - 05:00	660	93.17	2 - 06:00	360	94.22
2 - 23:00	480	83.03	3 - 00:00	360	81.82
3 - 08:00	420	83.68	3 - 18:00	360	88.75
3 - 17:00	360	90.06	4 - 12:00	360	94.77
4 - 07:00	1080	94.51	5 - 06:00	360	95.94
5 - 08:00	840	96.53	6 - 00:00	360	89.14
6 - 05:00	660	91.90			
6 - 23:00	480	83.14			
7 - 08:00	900	83.50			
8 - 07:00	960	93.26			

B2 Stealth Bomber

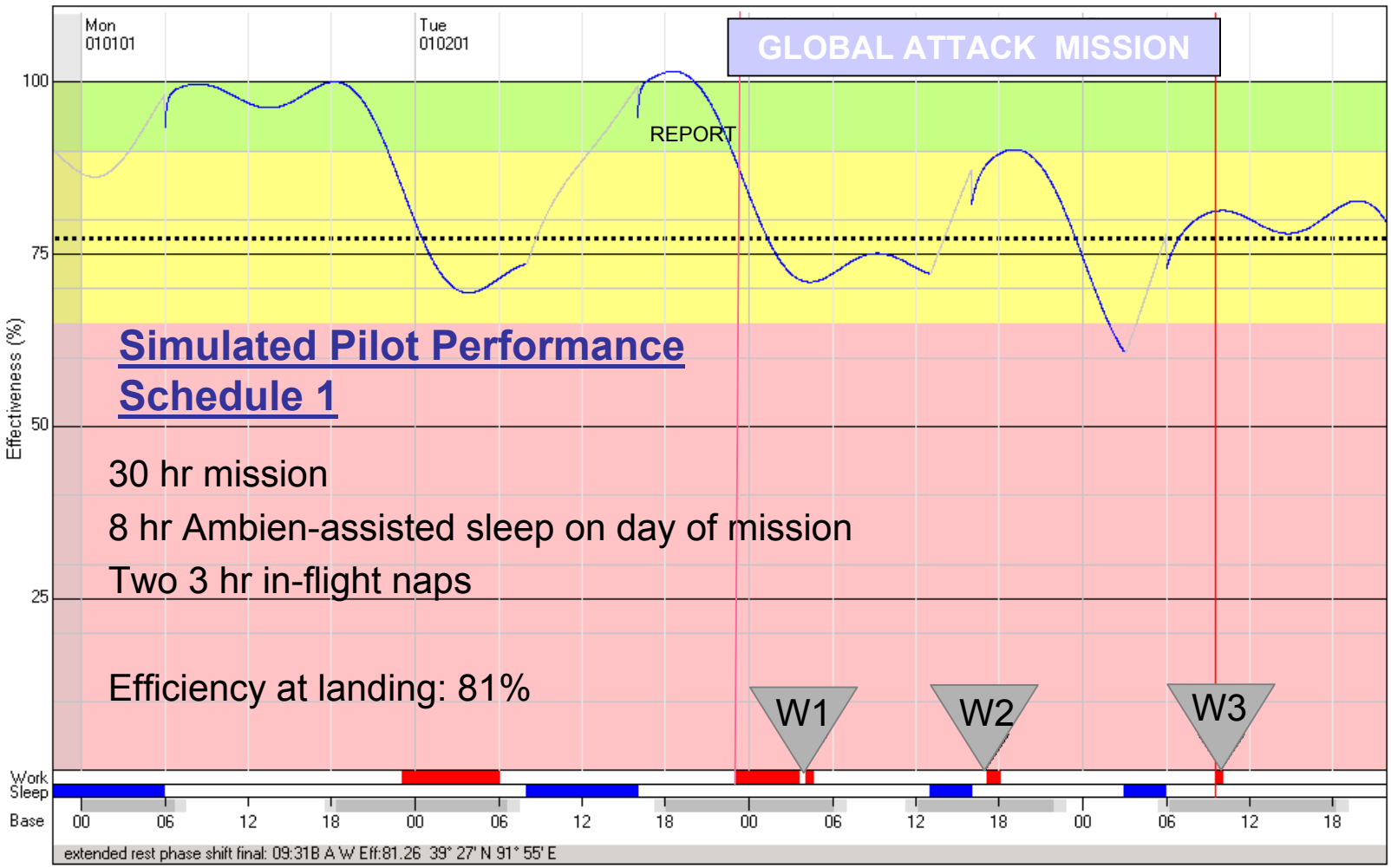
Fatigue Avoidance Scheduling Tool™
Mission Planning



Fatigue Avoidance Scheduling Tool™
Mission Planning

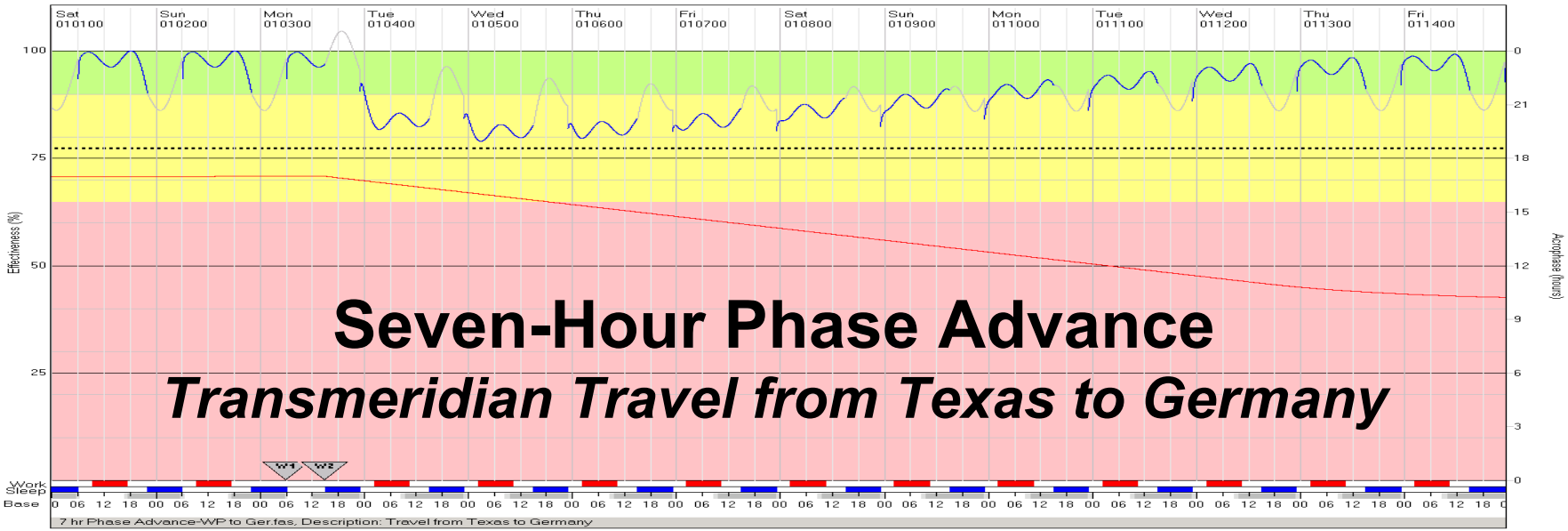


Fatigue Avoidance Scheduling Tool™
Mission Planning



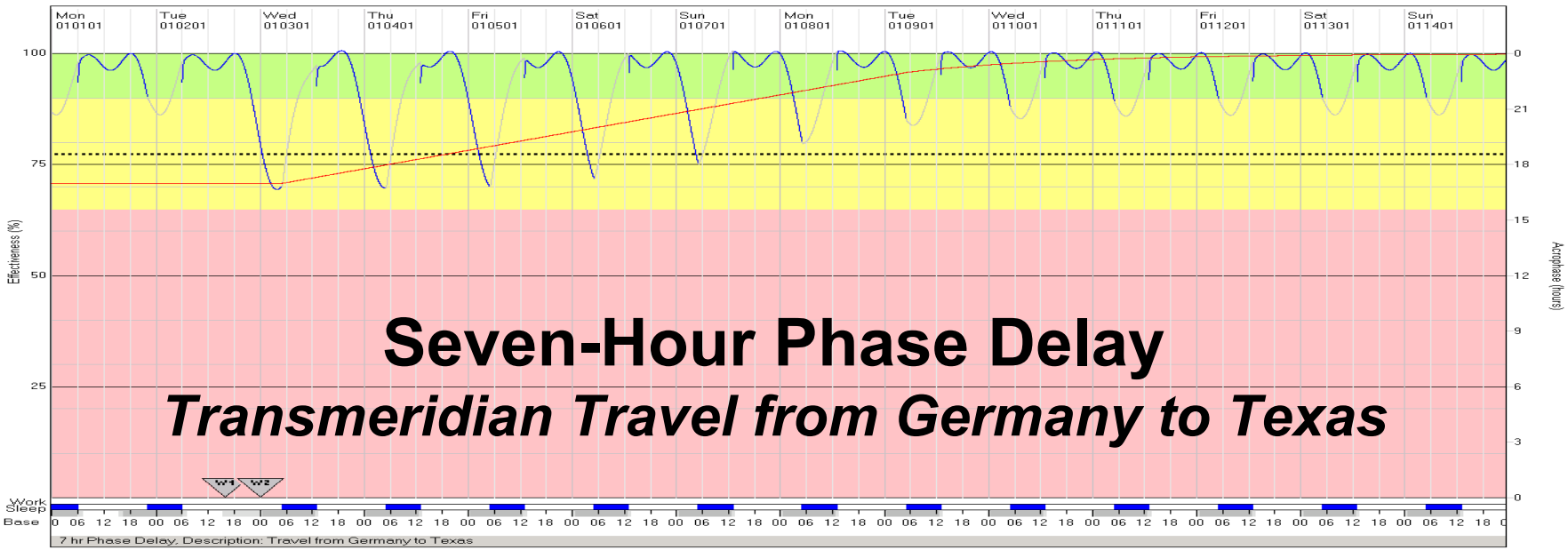
Lounge Chair Solution for In-flight Naps

"Jet-Lag" Effects



Seven-Hour Phase Advance

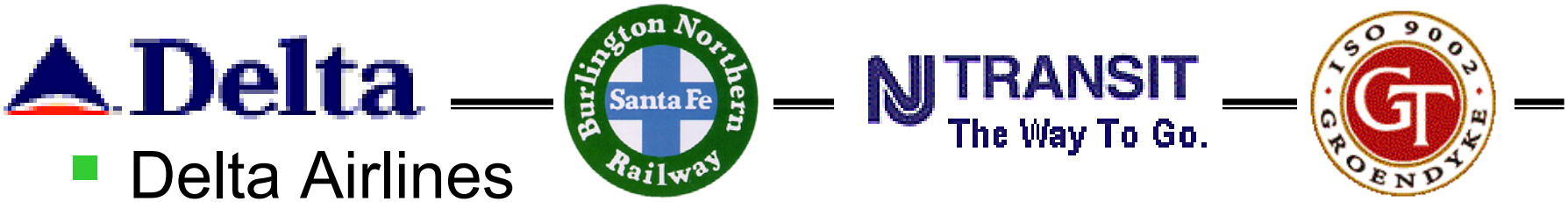
Transmeridian Travel from Texas to Germany



Seven-Hour Phase Delay

Transmeridian Travel from Germany to Texas

Current Corporate Interest



- Delta Airlines
- Burlington Northern Santa Fe Railroad
- New Jersey Transit
- Groendyke Transport
- Comanche Peak Nuclear Power Plant
- Susquehanna Nuclear Power Plant
- Palo Verde Nuclear Generating Station
- James A. FitzPatrick Nuclear Power Plant
- Eight other nuclear power plants
- Electric Power Research Institute
- Nuclear Energy Institute

FAST as a Work Schedule Tool

- Work schedule evaluation and design tool is intended to improve work and sleep scheduling based on predicted changes in performance.
  - ✓ Prospective decision aid based on *prognostic* model
  - ✓ Reliable and valid *ordinal* predictions are crucial.
  - ✓ Predictions based on normative estimates of sleep patterns and requirements for population of interest.
- May be used by management to design generic schedules
- May be used by employees as a self-management decision aid and training tool

FAST as an Accident/Event Investigation Tool

- Accident investigation tool is intended to evaluate the likelihood that fatigue was a participating cause in an accident.
  - ✓ Retrospective evaluation tool based on *diagnostic* model.
  - ✓ Reliable and valid *quantitative* predictions are required.
  - ✓ Predictions based on most accurate information available on work and sleep patterns of specific participants.
- Requires work schedule information from management and
- Requires employee sleep history

SAFTE™ Model Development

Identify Weaknesses – Research Solutions

- **Areas for improvement, all fatigue models:**
  - Individual differences between people
  - Recovery from chronically restricted sleep
  - Differential effects of sleep aids
  - Differential effects of alertness/wakefulness aids
  - Interactive effects of sleep aids and alertness/ wakefulness aids
  - Differential task responses to wakefulness & time of day
  - Differential effects of photic and non-photic cues on acrophase shifts
  - Relationship between circadian and circasemidian rhythms

Fatigue and Alertness Management using *FAST*™

End of Presentation

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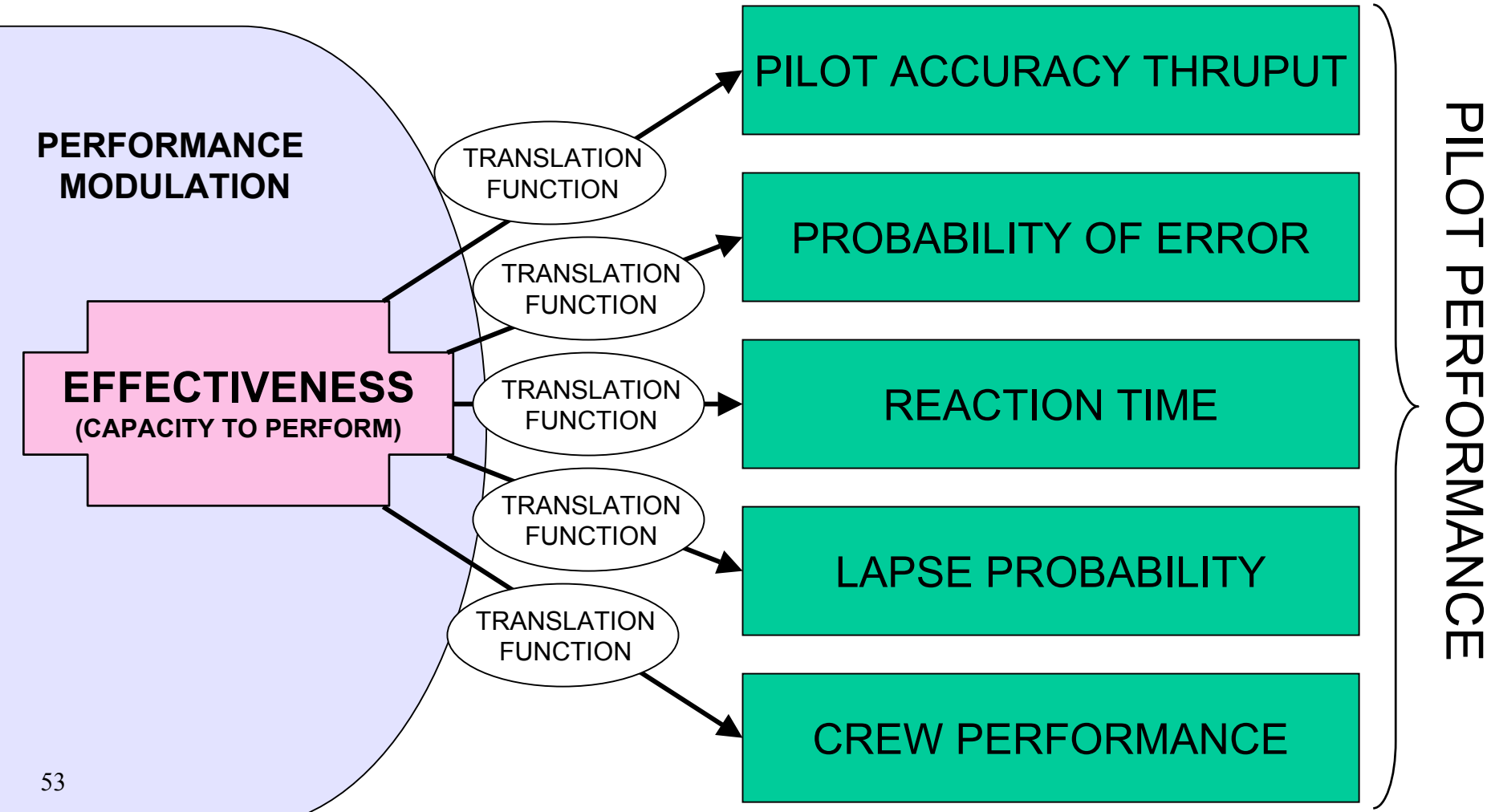
Key Features	Advantages
Iterative Process Simulation Model	• Effects of any schedule down to the minute • Effects of any sleep pattern • Adaptive to actigraph or temperature data
Homeostatic	• Declining sleep intensity during sleep period • Adaptive equilibrium of performance under less than optimal schedules of sleep
Multi-oscillator Circadian Process	• Asymmetrical cycle of performance
Clock Driven Circadian Process Event Driven Sleep-Wake Cycle	• Mid-afternoon dip in performance • Predominant early morning nadir in performance
Circadian Variation in Sleep Propensity and Intensity	• Circadian variations in sleep quality. • Limits on performance with day time sleep
Sleep Quality and Fragmentation	• Environmental effects on sleep quality • Sleep Apnea
Sleep Inertia	• Post-awakening slowing of performance
Dynamic Adjusting Circadian Phase	• Shift schedules and "jet lag" effects • Duration of adjustment
Rate of Phase Adjustment is Solar Light Sensitive	• Rate of phase adjustment to shift work is much slower than time zone adjustment • Reflects effects of light and social cues
Accounts for 90% of average performance variance during sleep deprivation	• Performance at extremes of sleep deprivation • Expected levels of performance under any combination of sleep and sleep deprivation
Task Effectiveness Parameters	• Predict variations relevant operator performance

SAFTE Model

PERFORMANCE TRANSLATION FUNCTIONS



Translation Function for Thruput of Correct Responses

Complex Reaction Time Task